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ENERGY-EFFICIENT OFFICE BUILDINGS: REPORT OF CANADIAN CASE STUDIES

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A.H. Elmahdy, Project Authority
Building Services Section
Division of Building Research

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PREFACE

Interest in reducing energy consumption in buildings has increased dramatically in the last decade. In Canada there have been initiatives to improve the thermal performance of houses, to convert from oil heating to other sources and to improve the energy performance of government buildings.

The Division of Building Research of the National Research Council of Canada undertook work to establish the energy-saving potential of office (and other type) buildings and to identify ways of achieving good energy performance. As a first step, energy use data for office, school, shopping centre and apartment buildings were gathered and analyzed. The results were characterized by a four to one or greater spread between the unit energy consumption of the worst and best performers. Although the reasons were not apparent, the spread suggested a considerable potential for energy savings.

Following this lead, DBR initiated contracts for studies to analyze, assess and document the energy performance and energy-conserving features (both physical and operational) of office buildings with much below average energy consumption. The results of those studies of seven relatively new buildings across Canada have been documented in detailed reports available through the Canada Institute for Scientific and Technical Information (CISTI).

To enable further dissemination of this information, the contractors were asked to present their results at a DBR-sponsored symposium in Ottawa in September 1983. This volume contains the papers presented at the symposium along with an edited version of the discussion. The papers are preceded by a brief overview and summary of the results by Dr. A.H. Elmahdy, who initiated the project and acted as project authority throughout.

I would like to acknowledge the efforts of Dr. Elmahdy in this regard, and to thank him for allowing me the pleasure of chairing the symposium.

R.C. Biggs
Head
Building Services Section
Division of Building Research

ENERGY-EFFICIENT OFFICE BUILDINGS
OVERVIEW AND SUMMARY

by

A.H. Elmahdy
Division of Building Research
National Research Council of Canada
Ottawa, Ontario

ENERGY-EFFICIENT OFFICE BUILDINGS: CANADIAN CASE STUDIES

by

A.H. Elmahdy

INTRODUCTION

Since the energy crisis of the early 1970's, extensive efforts have been devoted to search for ways and means to conserve energy in all building sectors, particularly commercial, institutional and residential buildings. Several conservation measures have been developed, aimed at reducing the total energy consumption in office buildings. These include improved systems and building designs as well as more energy-conscious operating procedures. Implementation of these conservation measures has resulted in a considerable reduction in the annual energy consumption of office buildings. By the early 1980's, about twelve percent of the total energy consumption in Canada was used in commercial and public buildings (1).

The Division of Building Research (DBR) of the National Research Council of Canada contributed to the technology transfer process by sponsoring a study to analyze and document the energy performance and conservation features of a group of low-energy office buildings. Seven consulting engineering firms were to each study a different low-energy office building, chosen according to predetermined building selection criteria. After the studies were completed, the analysts presented their findings at a two-day workshop, "Energy-Efficient Office Buildings", held in Ottawa in September 1983. Sponsored and organized by DBR, the workshop was attended by consulting engineers as well as representatives from various federal and provincial government departments.

This paper constitutes a part of the workshop proceedings which contain the seven papers presented by the consultants who participated in the study. Also included in the proceedings are summaries of the discussion that followed each presentation, and a summary of the general discussion at the end of the workshop.

Following the presentation of the seven case studies, this author (also the session's rapporteur) summarized the main results of the contract reports, in addition to some of the major issues raised in the analysis and during the discussion periods. The purpose of this paper is to introduce the workshop proceedings, provide more background on the study, and summarize the main issues of concern to building and system designers, and building energy performance analysts.

ENERGY CONSUMPTION OF OFFICE BUILDINGS

Recent surveys showed that actual purchased energy consumption of office buildings in Canada varied between 1000 and 4000 $MJ/m^2 \cdot yr$ (2,3) (Figure 1). Remarkable changes in energy consumption of office buildings occurred during the last three decades. Between 1950 and 1973, the average energy consumption in U.S. office buildings was rising and reached about 5300 $MJ/m^2 \cdot yr$ in resource energy. This upward trend was examined in a study

by Lawrence Berkeley Laboratory (LBL) (4). The study concluded that increasing consumption was due to the popularity of glass facades, very extensive area lighting (up to 65 W/m^2), and the use of oversized and inefficient heating, ventilating and air-conditioning (HVAC) systems.

This trend was reversed in the mid-seventies after the introduction of the voluntary ASHRAE Standard 90-75, which recommended a maximum energy budget of 2780 $MJ/m^2 \cdot yr$ in resource energy. Also, following the energy crisis, conservation programs started to have a substantial influence on annual energy consumption. Figure 2 shows the trends in resource energy consumption in U.S. and Swedish office buildings, in addition to cases of individual energy-efficient office buildings in Canada, the United States and Sweden. The point marked "LCC" in Figure 2 is the estimated life-cycle-cost minimum using 1980 technology, emphasizing the use of daylighting and thermal storage.

The term "resource energy" will be defined and discussed in the following section.

CANADIAN CASE STUDIES

The seven consulting engineering firms selected were asked to carry out their studies according to specified terms of reference. Each firm had to select a building with which it had no association during the design, construction or post-construction phases. To be selected, a building had to satisfy the following criteria:

Floor area (gross): 10 000 m^2 or more
Age: built after 1970
Height: 4 stories or more
Occupancy: office-type building with 95 to 100 percent occupancy during the years 1981 and 1982.
Recorded energy consumption: 1000 $MJ/m^2 \cdot yr$ or less purchased energy based on working space area for the years 1981 and 1982.

Table 1 gives pertinent information on each building along with the 1982 actual energy consumption, both site (purchased) and resource. The table also shows that all seven buildings satisfied the selection criteria with the exception of the E.I. Wood building, whose purchased energy consumption is about 4% higher than the target of 1000 $MJ/m^2 \cdot yr$ and whose gross floor area is about 17 percent lower than the minimum requirement of 10 000 m^2. The building was included, however, in order to ensure a fairly representative national sample.

Table 2 summarizes the main design features of the buildings. More details are given in the following individual papers and in the contract reports (5) available from the Canada Institute for Scientific and Technical Information.

SUMMARY OF RESULTS AND DISCUSSION

The breakdown of energy use in the seven buildings is shown in Table 3. The equipment load as a percentage of full load in the Revenue and Bell Canada buildings is very high compared to other buildings because of the extensive use of computers and office equipment.

All seven buildings have implemented various energy conservation measures. These features are related to four major areas: building envelope, HVAC system, lighting system, and operating procedures and controls (Table 4). Specific energy conservation features implemented in each building are shown in Table 5.

Improvements in HVAC system design and control strategies have contributed to the overall energy savings in office buildings. Heat pumps and heat recovery systems have been integrated with conventional HVAC systems, and compartmented variable air volume (VAV) units have replaced the single large VAV system in multi-storey office buildings. In addition, use of energy management and control systems (EMCS), either in a simple form or in a sophisticated configuration, has had a noticeable impact on energy consumption.

In the lighting area, delamping and the substitution of lower-wattage tubes have been the most effective energy-saving measure. The conventional lighting load of 50 W/m^2 or more has been reduced to between 18 and 36 W/m^2. The analyses have shown that improved lighting systems and the shut-off of lights during unoccupied hours accounted for about 40 to 60 percent of the overall energy savings. The second major energy-saving measure has been the reduced air circulation rates and HVAC system shut-off during unoccupied hours. This has accounted for about 25 percent of the overall energy savings. Other features such as heat recovery systems, reflective glazing, night temperature setback, free cooling and tightening of the building envelope have accounted for the remainder of the estimated energy savings.

The energy consumption of office buildings has been expressed in terms of "purchased (site)" energy and "resource" energy. The former represents the energy delivered to the building boundary, whereas the latter is intended to account for some conversion and transmission losses that occur before delivery to the building.

The purpose of using the resource energy in the assessment of the energy performance of buildings is to allow an equitable comparison to be made between buildings where various sources of energy are used. For example, electrically heated buildings may consume the least purchased energy for heating because there are no conversion losses in the transformation of electric energy into heat. This fails to account for the losses inherent in the generation and transmission of the electricity. Similarly, buildings heated by purchased steam appear to consume less energy than those where steam is generated in the building's heating plant. In the latter case, if fossil fuel is burned to generate steam, the conversion losses are "charged" to the building.

It is rather difficult to determine the correct multiplier to transform "purchased" energy into "resource" energy. For example, electric energy could be generated from a number of primary energy sources such as coal, gas

or oil, or generated in nuclear or hydroelectric power stations. Clearly, there are certain conversion losses associated with each method of electric energy generation, hence different multipliers. Moreover, it is common that the electric energy supplied to buildings is produced from a combination of two or more of the above described methods of electric energy generation. This makes it more difficult to arrive at a specific multiplier for electric energy.

Energy analysts tend to rely on their judgment when deciding upon the multiplier, which is influenced by the location, method and efficiency of conversion, and the purpose of the analysis. For example, in the study by LBL (4) the following multipliers were used:

Fossil fuel multiplier = unity
Electricity multiplier = 3

In another study published by LBL (6), the authors used 3.37 as the electricity multiplier. In a report recently published by the Building Research Establishment (7), the following multipliers were used:

Gas multiplier = 1.07
Electricity multiplier = 3.81

For the purpose of comparing the Canadian case studies with other cases available in the literature, the resource energy figures given in Table 1 were based on the following multipliers:

Electricity multiplier = 3
Gas multiplier = 1.1
Purchased steam multiplier = 1.3

It is common to normalize the annual energy consumption of "office buildings" using the "floor area". The lack of clear definitions of the terms "office building" and "floor area" might result in misrepresentation of data as well as inequitable assessment and comparison of the energy performance of buildings. The normalized energy consumption of a high-rise office building, where all of the working area is used as "office space", would be lower than that of another building where shopping malls and commercial areas occupy the ground floors. The main reason is the typically high lighting levels and the extensive use of incandescent lighting in commercial areas.

In practice, buildings fall into three major categories: residential, commercial and industrial (8). Commercial buildings include office buildings as well as high-rise buildings with mixed occupancy such as office and shopping areas. In situations where energy consumption of mixed-occupancy buildings is not separately metered for each type of occupancy, it becomes difficult to determine the actual energy consumption in the office space.

Regarding the use of the "floor area" to normalize the annual energy consumption, there will be differences in definition depending on the energy analyst. Floor area, however, may be one of the following: gross floor area (includes mechanical rooms, corridors and other service areas, but excludes indoor parking areas); net gross area (the same as gross area but

excludes mechanical rooms and elevator shafts); or net rentable area (includes only the floor area that could be leased to tenants -- measured from the inside of the building envelope.) As might be expected, the normalized annual energy consumption of a given building would have different values depending on the floor area considered in the analysis. On the one hand, many analysts use the gross floor area because it is already available off the blueprints of the building and is easy to identify. On the other hand, analysts in the real estate sector would prefer to use the net rentable floor area because other cost items are based on the unit area of rentable space. It may be that the use of net rentable floor area in normalizing the energy consumption is more appropriate because of its relationship to important economic determinants of the building's value in the marketplace.

It is difficult to identify a specific "floor area" that satisfies the objectives of all energy analysts. It would, however, be beneficial for all if the floor area used in normalizing the energy consumption is clearly defined and standardized.

The use of tinted glass and reflective coating on windows was described as a measure to save energy in office buildings. It was indicated that the reason for their use is to reduce the amount of short-wave radiation entering the conditioned space, and thereby reduce the cooling load, in addition to increasing the R value of the window. The information available about this energy conservation measure did not include any analysis to show its cost effectiveness, particularly for retrofitting existing buildings.

A reduction in the amount of both fresh and ventilation air is one of the measures taken to reduce energy consumption. Although some energy would be saved by implementing this action, It could result in poor air distribution and a deterioration in air quality in the working space. In turn it could have serious consequences on the productivity and health of employees. Consequently, it is essential to examine all the economic and health aspects of this measure prior to its implementation, particularly when the cost of the lost productivity could exceed the cost of energy saved.

Finally, one of the most commonly used energy conservation measures is the reduction of lighting energy either by reducing the number of tubes in the light fixtures or by replacing existing tubes with lower-power tubes. Although delamping of light fixtures results in reduced electrical energy consumption, this may result in poor lighting. There may also be a reduction in the service life of lamps and ballasts if the delamping is not done properly. The associated cost of replacing lamps and ballasts together with the effect of poor lighting on productivity should be taken into account when estimating the cost effectiveness of such action. In addition, the reduction in lighting energy use would reduce internal heat gains within the conditioned space. This means that additional heating may have to be supplied by the heating system, thereby reducing the apparent savings somewhat. Similarly, delamping would also reduce the cooling load particularly in interior zones. Accordingly, the cooling requirement would be reduced and since the central cooling plant would operate at a lower fraction of its design load, its coefficient of performance would be reduced slightly. However, if this energy-conservation measure were considered at

the design stage of a new building, substantial cost savings could be realized by the reduction of cooling and air distribution equipment.

SUMMARY

A study of seven energy-efficient office buildings in Canada showed that several factors have contributed to a reduction in energy consumption. Major energy conservation features are related to four areas: the building envelope, the heating, ventilating and air-conditioning (HVAC) system, the lighting system, and operating procedures and controls. HVAC and lighting systems shut-off during unoccupied hours is the most effective energy-saving measure, followed by a reduction in fresh and ventilation air rates. The latter may, however, result in some deterioration in air quality and consequent lower productivity in the working space. Also, there is a need to quantify the impact of delamping programs on heating and cooling energy requirements, and HVAC system performance particularly when the delamping is part of retrofit programs.

There needs to be a standardized definition of terms such as office building itself, resource energy, and floor area used in normalizing the annual energy consumption. Comparison of the thermal performance of office buildings will not be meaningful or equitable until common terms are clearly specified and accepted by energy analysts and other parties concerned.

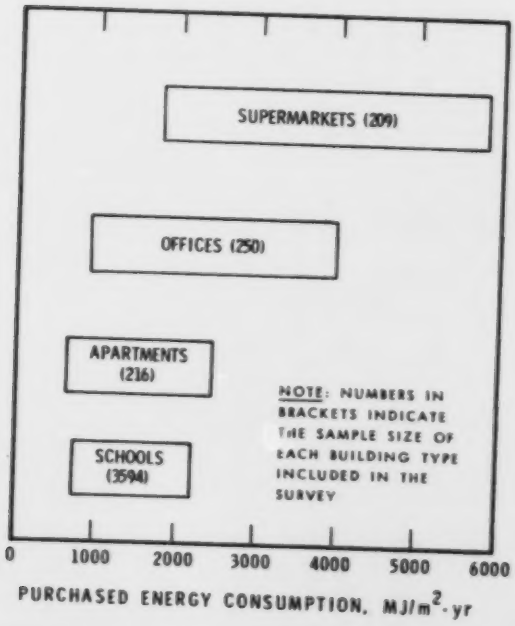

FIGURE 1

RANGE OF PURCHASED ENERGY CONSUMPTION FOR VARIOUS CLASSES OF BUILDING

BR 6540-1

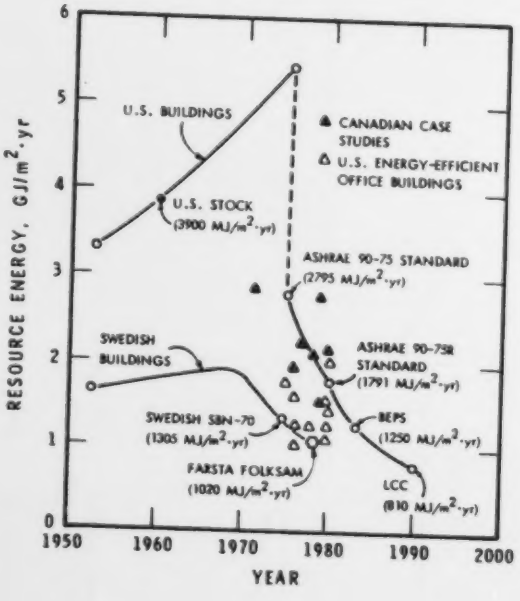

FIGURE 2

TRENDS IN RESOURCE ENERGY CONSUMPTION

BR 6540-2

TABLE 1. Summary of Information on Seven Energy-Efficient Office Buildings

No.	Building	Location	Contractor	Floor Area m^2	Year Built	No. of Stories	1982 Purchased Energy Consumption $MJ/m^2 \cdot yr$				Resource Energy* $MJ/m^2 \cdot yr$
							Elect.	Gas	Steam	Total	
1.	Joseph Shepard	Toronto, Ont.	Giffels	60 191	1978	13	650	132	-	782(1)[a]	2095(3)[b]
2.	Revenue Building	Ste. Foy, Qué.	CRS Inc.	83 849	1979	6	911	-	-	911(4)	2733(6)
3.	Marsland Centre	Waterloo, Ont.	Acres	10 300	1971	13	942	-	-	942(6)	2826(7)
4.	Red Deer Provincial Building	Red Deer, Alta.	Vinto	20 500	1979	6	323	601	-	924(5)	1630(1)
5.	E.I. Wood Building	Swift Current, Sask.	Yoneda	8 270	1977	5	564	479	-	1043(7)	2219(5)
6.	Government of Canada	London, Ont.	Engineering Interface	19 963	1976	11	519	8	282	809(3)	1932(2)
7.	Bell Canada Administrative Bldg.	London, Ont.	Chorley and Bissett	33 700	1980	9	681	11	108	800(2)	2196(4)

Resource Energy = Electrical × 3 + Gas × 1.1 + Steam × 1.3
a - Ranking according to purchased (site) energy index.
b - Ranking according to resource energy index.

TABLE 2. Summary of the Main Design Features of Seven Energy-Efficient Office Buildings

Building	Wall Construction	Windows	HVAC System	Lighting Power	Others
Joseph Shepard	Brick & block spandrel	Double-glazed	Compartmented VAV system & perimeter heaters	24.8 watts/m^2	-heat recovery system -thermal storage (1135 m^3 water)
Revenue Building	Prefabricated insulated metal	-reflective glass -thermo double-glazed 46% of exterior wall	decentralized low velocity fan coil	21.4 watts/m^2	-780 heat pumps for perimeter zones -1325 m^3 water thermal storage
Marsland Centre	Prefabricated concrete panels	double-glazed grey thermopane 19% of exterior wall	high velocity with electric duct heating	36.4 watts/m^2	all-electric building
Red Deer Provincial Building	Precast concrete	double-glazed with medium solar bronze pane 28% of exterior wall	VAV with economize and perimeter heaters	22.6 watts/m^2	tight wall construction
E.I. Wood	Precast concrete	double-glazed with grey reflective pane 30% of exterior wall	VAV system	19.7 watts/m^2	
Government of Canada	Precast concrete	double-glazed 25% of exterior wall	VAV compartmented fan units	34.2 watts/m^2	
Bell Canada	Aluminum panels	sealed double-glazed tinted units 28% of exterior wall	-mixed air system -perimeter heating by high pressure induction -mixed air VAV units	18.3 watts/m^2	core areas cooling only

TABLE 3. Breakdown of Energy Use (percentage of total)

Load	Joseph Shepard	Revenue Building	Marsland Centre	Red Deer Provincial	E.I. Wood	Government of Canada	Bell Canada
Lighting	46.5	29.4	29.3[a]	28.6[d]	36.5[d]	40	35.0
Heating	15.0	26.6	29.3	63.6[c]	41.5	37.7	6.1
Cooling	14.0	6.0	3.7	1.9[c]	3.8	5.0	8.1
Fans & Pumps	13.3	17.2	27.5	2.2	14.7	13.7	12.9
Equipment (computer, etc.)	6.5	13.3	-	-	-	1.3	17.5
Domestic Hot Water	1.7	0.3	1.2[b]	2.4	0.4	1.5	1.9
Miscellaneous	3.0	7.2	9.0	1.3	3.1	0.8	18.5[e]
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]includes equipment [c]includes electrical auxiliary loads [e]includes circulating pumps
[b]includes elevators [d]includes office equipment

TABLE 4. Summary of Energy Conservation Features

Building Envelope	HVAC System	Lighting System	Operational Control
Reduced glass area	Use of economizers and use of free cooling, when possible	Reduce lighting power	Use of energy management and control systems
Use of multiple-glazing sealed units	Use of heat pumps	Use of high performance lighting system	Shut-off of lights and HVAC during unoccupied hours
Use of reflective coating windows	Use of heat recovery	Use of task lighting	
Use of shading devices	Use of VAV and minimize reheat energy	Use of daylighting	Electricity demand control
		Delamping	
Improve air-tightness to reduce infiltration	Use of thermal storage		Minimize simultaneous heating and cooling
Increase insulation in exterior walls	Reduce ventilation rates without deterioration in air quality		Supply temperature reset Night-time temperature setback Use of carbon monoxide detectors to control ventilation rates

TABLE 5. Energy Conservation Features Implemented in Each Building

Energy Conservation Feature	Joseph Shepard	Revenue Building	Marsland Centre	Red Deer Provincial	E.I. Wood	Government of Canada	Bell Canada
1. Delamping	✓		✓		✓	✓	
2. Lights shut off (unoccupied hrs)	✓	✓		✓		✓	✓
3. Reduce lighting power	✓	✓	✓	✓	✓		✓
4. Systems shut-off (unoccupied hrs)	✓		✓	✓		✓	✓
5. Improved HVAC design	✓			✓	✓	✓	
6. Heat recovery	✓	✓			✓	✓	✓
7. Reduce Ventilation rate (and outdoor air)	✓	✓	✓				
8. Improve control system	✓		✓	✓	✓	✓	✓
9. Reflective coating windows (or tinted glass)		✓	✓	✓	✓		✓
10. Reduced glass area						✓	
11. Thermal storage	✓	✓					
12. Others		✓	✓	✓		✓	

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ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE MARSLAND CENTRE
WATERLOO, ONT.

by

Bernard D. Deuchars, P.Eng.
Acres Consulting Services Ltd.
Burlington, Ont.

Marsland Centre

AGHS

CASE STUDY OF AN
ENERGY EFFICIENT OFFICE BUILDING
THE MARSLAND CENTRE
WATERLOO, ONTARIO

It is a pleasure to be afforded this opportunity to speak to you.

I will be speaking to you about the Marsland Centre, located in Waterloo, Ontario. However, before getting into that topic, I'll relate to you an anecdote concerning what appeared to be the ultimate in energy efficient building design.

One of our large institutional clients operates a central steam generation and distribution system. Heating energy to the buildings which comprise the institution is metered using condensate meters. User departments within the institution are "charged" for energy use through an internal accounting procedure. One of the affiliated colleges, (this being a university client), underwent an expansion project. After completion of the new addition, the Physical Plant Dept. who supply the steam, noted that metered condensate returned from the college to the steam plant was less per month than before the expansion project, despite similar weather and usage conditions. The plant operator in the affiliated college suggested that this phenomenon might be attributed to the energy efficient design of the new building addition. Needless to say, this explanation "didn't wash" with the Physical Plant Department, and it was subsequently discovered that a considerable volume of the condensate was being inadvertently sewered upstream from the condensate meter. Matters have since been rectified, and the Physical Plant Department has now engaged Acres to install steam metering for some of the major users on the campus.

* * * * * * * * * *

The Marsland Centre in Waterloo, Ontario is a thirteen-storey steel frame office tower with a gross floor area of 10,300 square meeters (111,000 square feet). Its design was patterned after a building in Singapore which was admired by the building owner, Mr. Stanley Marsland. The architects for the building were Barnett, Reider-Hymmen, of Kitchener, Ontario. The structural engineers were Walter, Fedy, McCargar, Hatchburn of Kitchener. The mechanical/electrical engineers were Yuska Wenzel and Sehl Ltd. of Kitchener. The general contractor was Lavern Asmussen Ltd. of Kitchener. The property manager is Mr. Carl H. Schmidt, whose offices are located at the top floor of the Marsland Centre Building.

The building was designed in 1969/70 and constructed in 1971. It achieved substantially full occupancy in 1974. The princi-

pal tenants are the Regional Municipality of Waterloo and the City of Waterloo. Other tenants include several insurance companies, a bank branch, and a consulting engineering firm.

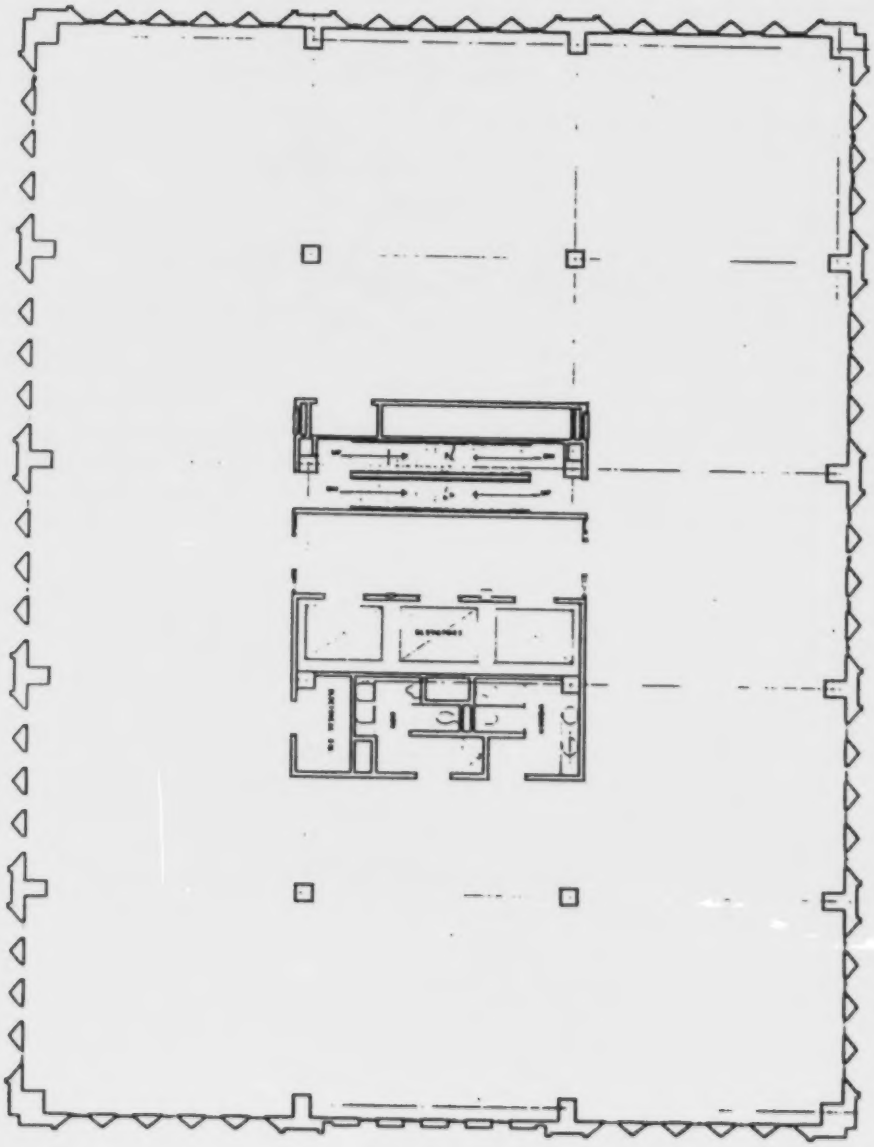
The Marsland Centre is an all electric building, employing electric resistance heating and electrically driven centrifugal chillers for summer cooling. (Mr. Marsland, the owner, was formerly an electrical contractor, hence he had a soft spot in his heart for all-electric installations.) In view of its being electrically heated, the building envelope was designed with more than the (then) normal amount of thermal insulating properties. I will elaborate on this shortly.

In order to be selected for the NRC study of energy-efficient office buildings, a candidate building had to satisfy a number of criteria concerning building height, gross floor area, and of course, unit energy consumption, among other requirements. The unit energy consumption requirement was to be not in excess of 1000 $MJ/m^2.y$ (26 $EkWh/ft^2.y$). The Marsland Centre, as operated in 1974 following full occupancy, did not meet this performance parameter by a wide margin. During calendar years 1974, 1975 and 1976, the normalized unit energy consumption was 1360 $MJ/m^2.y$ (35.1 $EkWh/ft^2.y$). However, commencing in 1977, the property manager introduced numerous operational changes and retrofits designed to reduce both energy demand and consumption. As a result of these changes, the normalized unit energy consumption of the Marsland Centre has been reduced to 942 $MJ/m^2.y$ (24.3 $EkWh/ft^2.y$), an improvement of 30 percent over pre 1977 values.

At the same time, average monthly electrical demand has been reduced 22%, from 894 kW/month to 701 kW/month. Through these measures, which will be discussed shortly, the property manager and owner have nullified the considerable increase in annual electrical costs which would have occurred as a result of price escalation between 1976 and the present.

As mentioned above, the pre-1977 unit annual energy consumption of the Marsland Centre was 1360 $MJ/m^2.y$ (35.1 $EkWh/ft^2.y$). While this is not what might be considered good energy performance by today's standards, it certainly was considered good at the time of its design in 1969/70, when unit energy consumption values of up to 5800 $MJ/m^2.y$ (150 $EkWh/ft^2.y$) were not uncommon. Let us examine some of the conservation-minded construction features which were incorporated into the original design.

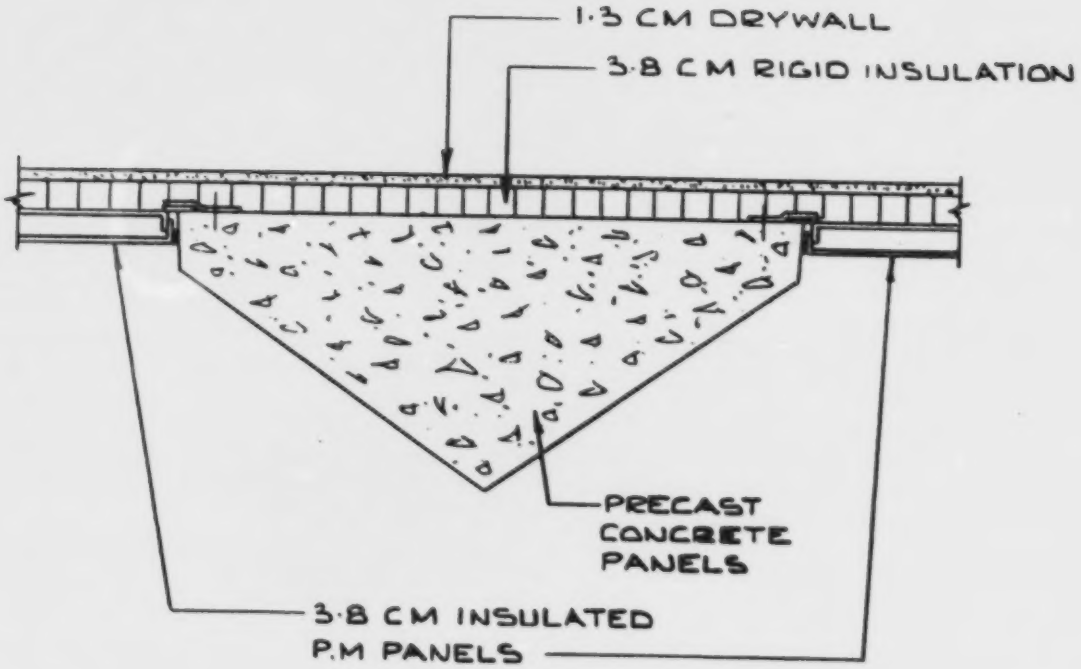
Here is a typical floor plan of the Marsland Centre. It is a standard rectangular office building design, with rentable space surrounding the central service core containing stairwell, elevators, washrooms, and service rooms. The rentable



TYPICAL FLOOR PLAN

MARSLAND CENTRE WATERLOO

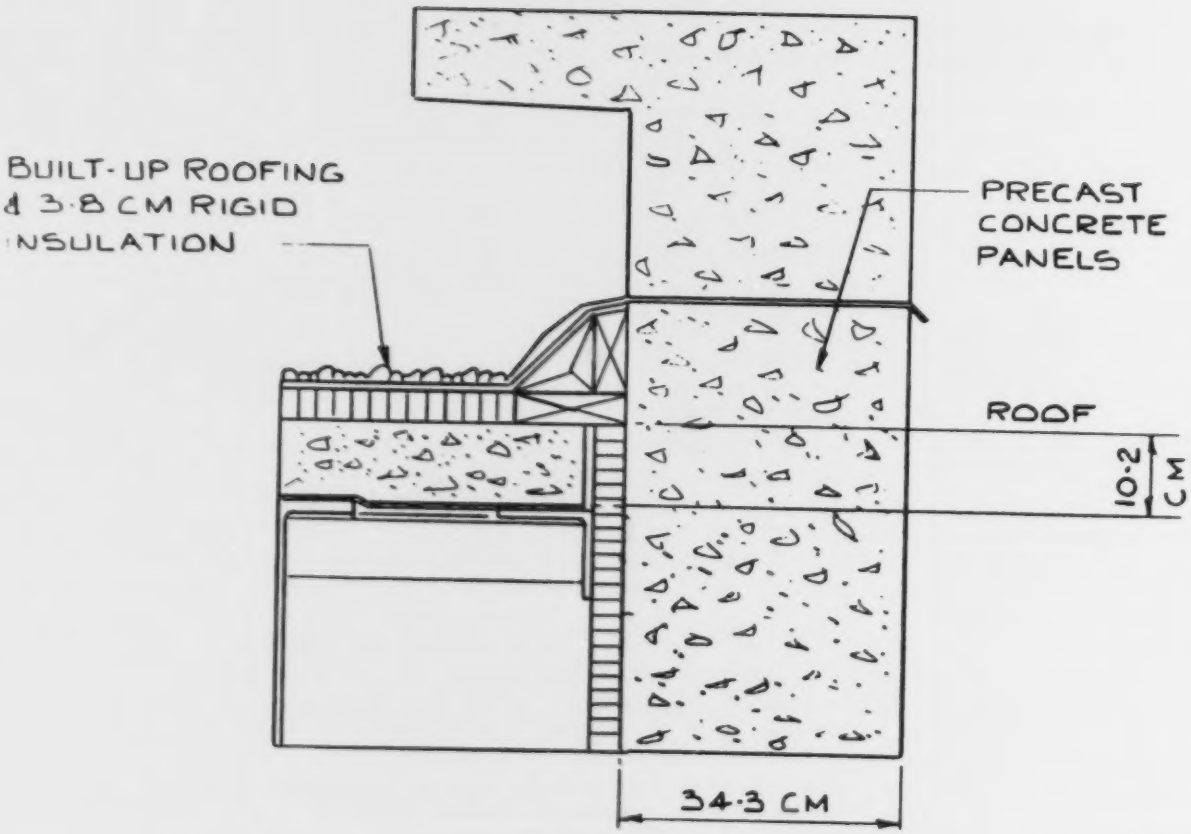
Fig. 2-1



TYPICAL HORIZONTAL WALL SECTION

MARSLAND CENTRE WATERLOO

Fig. 2-2



TYPICAL ROOF SECTION

MARSLAND CENTRE WATERLOO

Fig. 2-3

space is itself subdivided by light wall partitions in accordance with tenant requirements.

The exterior walls are precast concrete panels and pre-manufactured insulated panels, all backed by 3.8 cm (1.5 in.) of rigid insulation and 1.3 cm (1/2 in.) of dry wall. The exterior wall overall RSI value is 1.98 (R11).

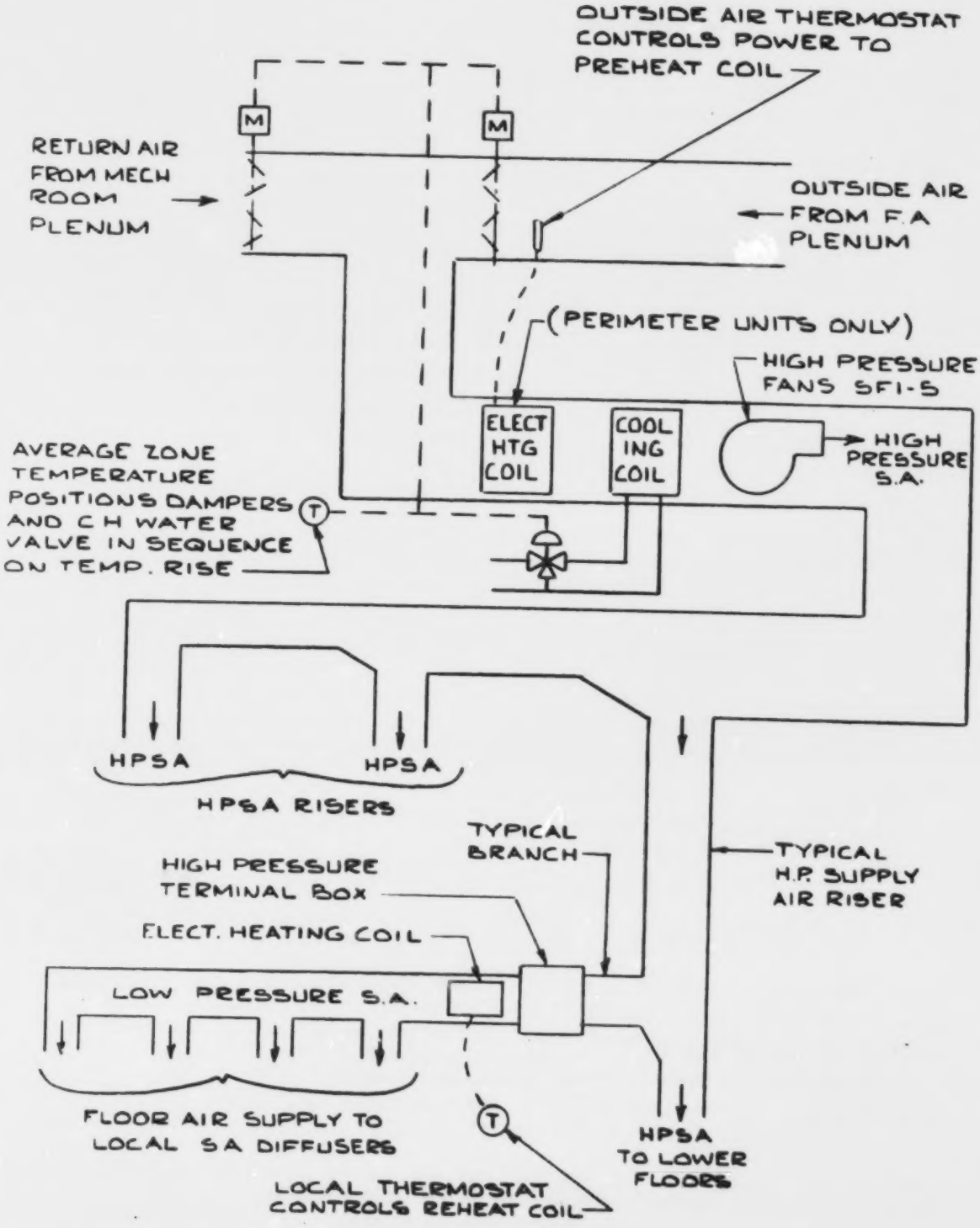
There are 800 windows, all insulated units, tinted gray thermopane solar glass having an RSI value of 0.36 (R2). The ratio of glass to wall area is 19 percent.

The roof of the building comprises 10 cm (4in.) concrete deck with 3.8 cm (1.5 in.) of styrofoam insulation and built-up roofing. The RSI value of the roof is 1.05 (R6).

As mentioned earlier, the building is all electric. Heating is provided by electric resistance heaters mounted in the supply air ductwork, and by perimeter baseboard units. Summer cooling is provided by an electrically driven centrifugal chiller. All electric power for heating, cooling, lighting and equipment is metered through a single demand/ energy meter.

The building interior lighting is predominantly fluorescent comprising two-tube and four-tube ceiling mounted fixtures which double as supply air and return air grilles. Local switching of lighting is provided for the convenience of tenants. This feature is inherently energy-conserving because it facilitates shutting off lighting which is not required.

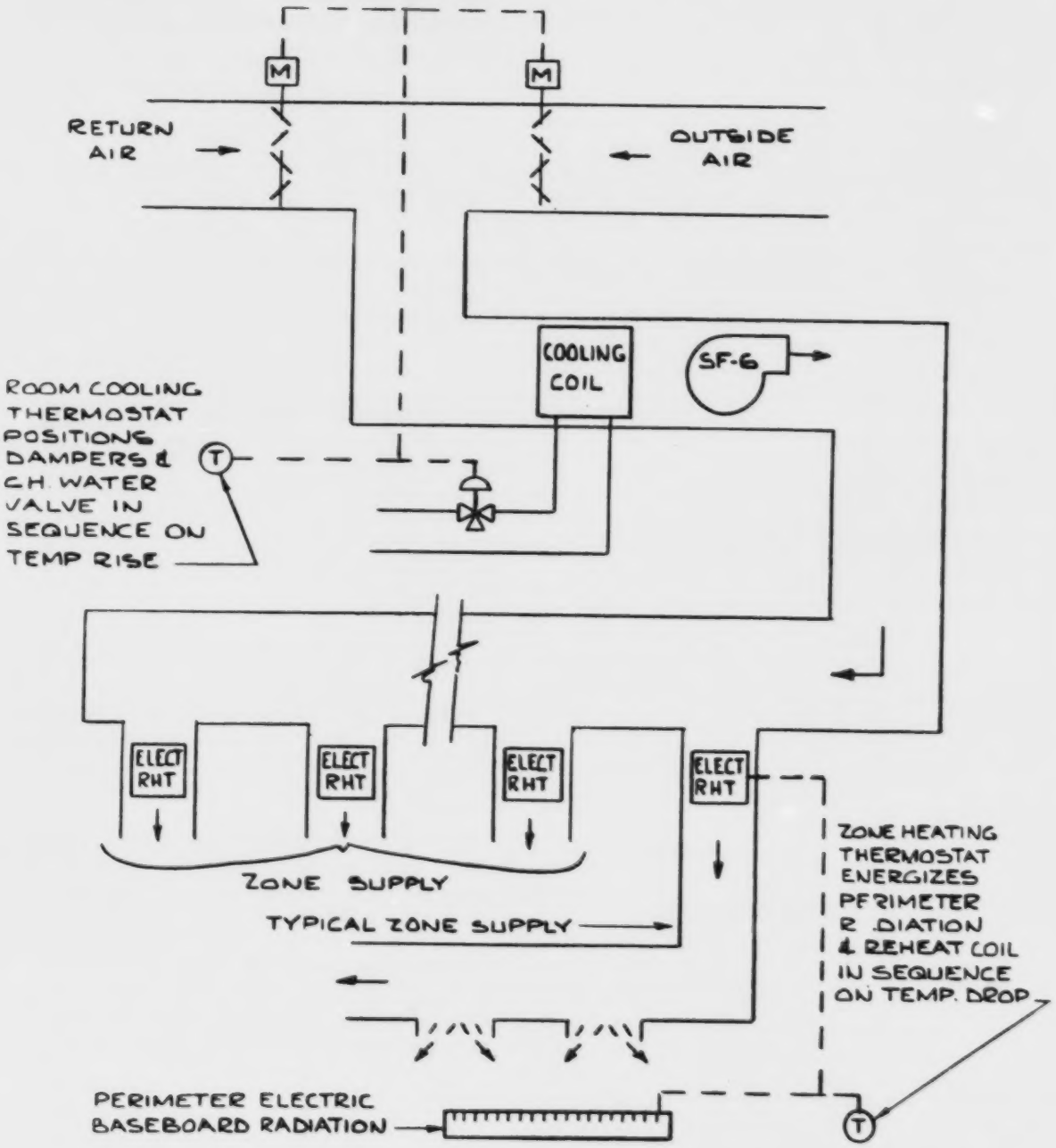
The heating, ventilating and air conditioning of the second through thirteenth floor is provided by five high pressure supply air systems and one common return air system. The fans are located in a 13th floor mechanical room. Four of the supply air systems serve the four perimeter exposures of the building and include electric preheat coils and cooling coils located at the units; and reheat coils located in branch ductwork to groups of perimeter air discharge outlets. The fifth supply air system serves the interior core of the building; it has no preheat coils, only reheat coils in the branch ductwork to air supply light troffers. Air is returned to ceiling plenums through light troffers from where it passes into a return air shaft. The common return air fan discharges into the mechanical room which acts as a common return air plenum. Each supply air system is equipped to mix return air with outside air. Provision for "free cooling" is incorporated in the temperature control scheme, with the outside air dampers reverting to a minimum position setting of 15 percent at an outside air temperature of 19.4°C.



SCHEMATIC DIAGRAM OF HIGH PRESSURE SUPPLY SYSTEMS FOR FLOORS 2-13
MARSLAND CENTRE WATERLOO

Fig. 2-4

ACRES



SCHEMATIC DIAGRAM OF SUPPLY AIR SYSTEM
FOR FIRST FLOOR AND BASEMENT

Fig. 2-5

MARSLAND CENTRE WATERLOO

AGRES

The supply unit preheat coils are controlled to come on in stages in response to dropping outdoor temperature. The reheat coils are controlled by local room thermostats. An automatic "night" setting control feature causes the units to be controlled by a night thermostat set at 18.3°C, and the units go onto 100 percent recirculation.

The heating, ventilating and air conditioning of the first floor and basement are provided by a multizone air handler and two small fan systems located in a first floor mezzanine mechanical room. The control of these units is similar to the main units serving floors 2 to 13. The first floor also incorporates electric baseboard perimeter radiation because of the large glazed areas.

Electric snow-melting cables are embedded beneath the podium steps at the four corners of the building. Power to these cables was manually controlled. Their use has been discontinued for operational and conservation reasons.

An additional energy conservation feature incorporated into the original design of the building was the capture of heat released by electric apparatus located in electrical rooms throughout the building. The electrical rooms exhaust system can be discharged either to the return air plenum, or to outside, depending on whether heating or cooling is required.

The Marsland Centre, being all electric, attracted the attention of Ontario Hydro which, in December 1973, featured it in its "Concept Electric" publication which was devoted to energy efficient buildings and processes.

Despite the Marsland Centre being a conservation showpiece of its time, the building owner and property manager were aware that improvements in energy management were desirable and possible. Despite being a "showpiece", the following shortcomings in design and operation vis-a-vis conservation, became apparent:

- the high pressure high velocity air handling systems used large quantities of electrical power for air movement, especially as they were run continuously day in-day out, every day of the year.

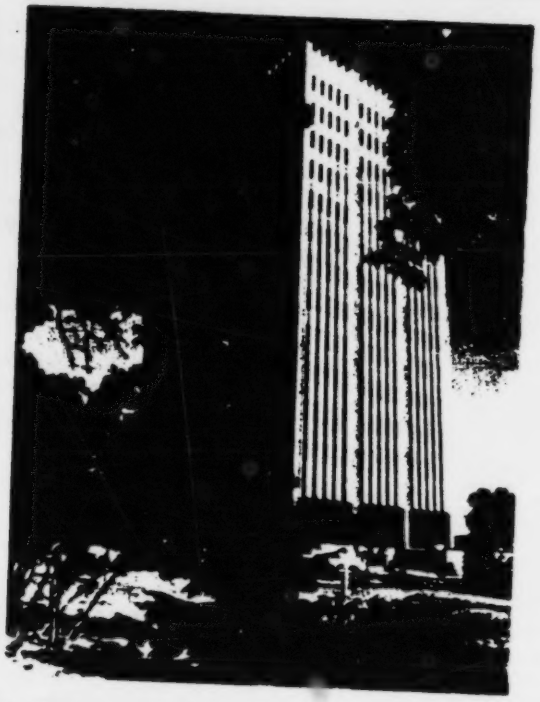
- the air handling systems are all reheat systems, presenting the possibility of simultaneous heating and cooling

- the air preheat coils in the perimeter air handling systems presented the possibility of simultaneous operation with attendant high electrical kW demand

CONCEPT ELECTRIC

December, 1973. No. 69

Marsland Centre, Waterloo



HEAT RECOVERY SYSTEM IS TOTALLY ELECTRIC IN MARSLAND CENTRE, WATERLOO PRESTIGE OFFICE TOWER

The tallest office building in Waterloo, Marsland Centre, towers 182 feet and 13 storeys above the downtown area of the city. It provides almost 100,000 square feet of office space for 600 occupants – all electrically space conditioned. Two of the floors are occupied by the city administration.

Marsland Centre sits on a 20-foot decorative concrete podium, landscaped with flowers and trees to provide an attractive entrance and a welcome pause for visitors on a busy day. It is faced with more than 900 vertical pre-cast concrete panels, some of which are inlaid with red man-made granite. The contrasting red and white panels accent the vertical lines of the structure.

The 800 windows of gray thermopane solar glass reduce heat and glare but allow natural sunlight to filter through. Double glazing forms one of the insulation components.

Built two years ago, Marsland Centre was the first building of its size in Waterloo to be heated and cooled totally by electricity. The system makes effective use of power by re-using heat given off within the building from transformers, motors, lighting and business machines. The heated air is collected, cleaned and recirculated.

Fluorescent lighting provides 95-100 foot-candles at floor level.

Fire detectors in all areas feed signals to a master control panel with each floor having a fire-hose cabinet. The building has its own water-pressure system.

Marsland Centre, Waterloo

STRUCTURE

13 storey office building, 7,550 sq. ft. of space per floor. 1,374,100 cu. ft. 182 ft. high. 600 occupants.

CONSTRUCTION

Exterior walls: precast concrete panels + 2" styrofoam insulation.
Frame: structural steel. Foundation: building rests on 24 concrete caissons sunk to average of 40' below surface. Floors: concrete. Roof: 4" concrete + 1½" styrofoam. Windows: double glazed gray thermopane solar.
Ratio of glass to wall area: 19%. Doors: glass

DESIGN DATA

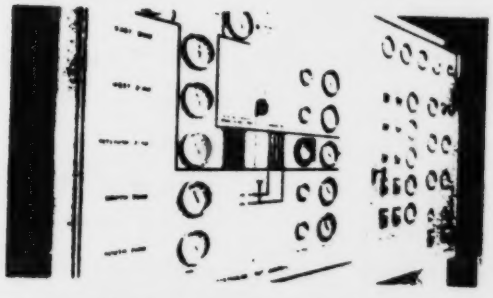
Winter: Outdoor design temp, 3°F. Normal degree days, 7566.
Indoor design temp, 72°F. Ventilation, 110,400 cfm re-system with minimum of 15% of fresh air.
Summer: Outdoor design temp, 90°F. Indoor design temp, 75°F.

SPACE CONDITIONING DATA

The heating system is an all-air system, with both the air return and supply to the core through the lighting fixtures. The perimeter heating is a high velocity air system with electric duct heaters to supply air at desired temperatures. Each 20 by 20 foot space is controlled by its own thermostat regulating the perimeter heating. The temperature of the supply air to the core of the building is regulated by mixing return air with outside air to supply a temperature of approximately 60°F. Once the outside temperature reaches 60°F, a 300 ton air conditioner takes over to supply the cooling.

By utilizing the heat returned through the light fixtures and re-using this heated air, after it is mixed with fresh air for the perimeter, a very economical installation is obtained. Also heat released from transformers and motors is picked up in the air stream and utilized.

CONTROLS



Night setback with time clock control on each floor to stagger loads coming on in morning.

ELECTRICAL SERVICE DATA

Underground service. Transformation by owner: 2,000 kva. 14.2 kv primary, 600 V – 3Ø secondary with 150 kva, 600 V to 120/208 V dry type transformer on each floor.
(Note: Ø is a symbol for three-phase)

CONNECTED LOADS

Heating: 1,222 kw. Cooling: 300 ton. Lighting 375 kw. Water heating: 34 kw.

OTHER ELECTRICAL LOADS

Lighting level: 100 footcandles. Domestic water heating: bulk central storage.

CAPITAL COST

Heating, cooling, ventilation, lighting, mechanical: $4.60 per sq. ft. Electrical, $2.80 per sq. ft.

OPERATING DATA

Month		kwh	kw	L.F.	Net Cost
April	1972	279,600	936	41.4%	$ 3,597.85
May	1972	340,800	720	69.7%	3,648.25
June	1972	222,000	648	47.5%	2,690.65
July	1972	252,000	564	62.0%	2,753.65
August	1972	249,600	576	60.1%	2,797.85
September	1972	248,400	552	62.5%	2,707.45
October	1972	271,200	552	68.2%	2,867.05
November	1972	268,800	696	53.6%	3,102.25
December	1972	276,000	816	46.9%	3,362.55
January	1973	366,000	936	54.3%	4,202.65
February	1973	426,000	984	60.1%	4,706.65
March	1973	325,200	984	45.9%	4,001.05
		3,525,600			40,397.90

Average net cost per kwh = 1.14c
Annual Energy = 35.3 kwh/sq. ft.
Annual Cost = 40.4c/sq. ft.
Maximum Demand = 9.8 watts/sq. ft.

CONSULTANTS

Architects: Reider–Hymmen, Kitchener.
Mechanical & Electrical: Yuska, Wenzel & Sehl Ltd., Kitchener.
Utility: Waterloo Hydro

Owner & Developer: Stanley Marsland, Waterloo, Ontario

TECHNICAL DATA VERIFIED BY:

Samuel Yuska,
Yuska, Wenzel & Sehl Limited,
Kitchener, Ontario.

Published by Ontario Hydro, Commercial/Industrial Sales Dept., 620 University Ave., Toronto, M5G 1X6

- most office areas were found to be over-illuminated in the opinion of the users of the space

- outdoor decorative lighting was excessive

- some electric storage water heaters were found to be redundant

- the podium snow melting system was found to create more problems than it solved. It creates the possibility of increasing the electric kW demand. At the same time, melted snow and ice refroze at new unprotected locations, creating slippery and hazardous conditions for pedestrians. (Electric snow melting was soon abandoned in favour of applying ice pellets.)

- occupant access to heating thermostats.

The calendar year of 1976 was chosen as the "milestone" year against which to measure the effects of energy conservation measures which were introduced by the property manager. You will remember that 1976 was the first year of full occupancy, and that few conservation measures had been introduced to that point.

This exhibit shows the month-by-month and annual level of energy consumption in kWh for the Marsland Centre in 1976. Note the breakdown of energy use into the main components of

- lighting, office equipment, DHW and elevators
- air movement
- heating
- cooling.

The breakdown into main components was done with the aid of a computer simulation model (the Merriwether/ PWC ERE program).

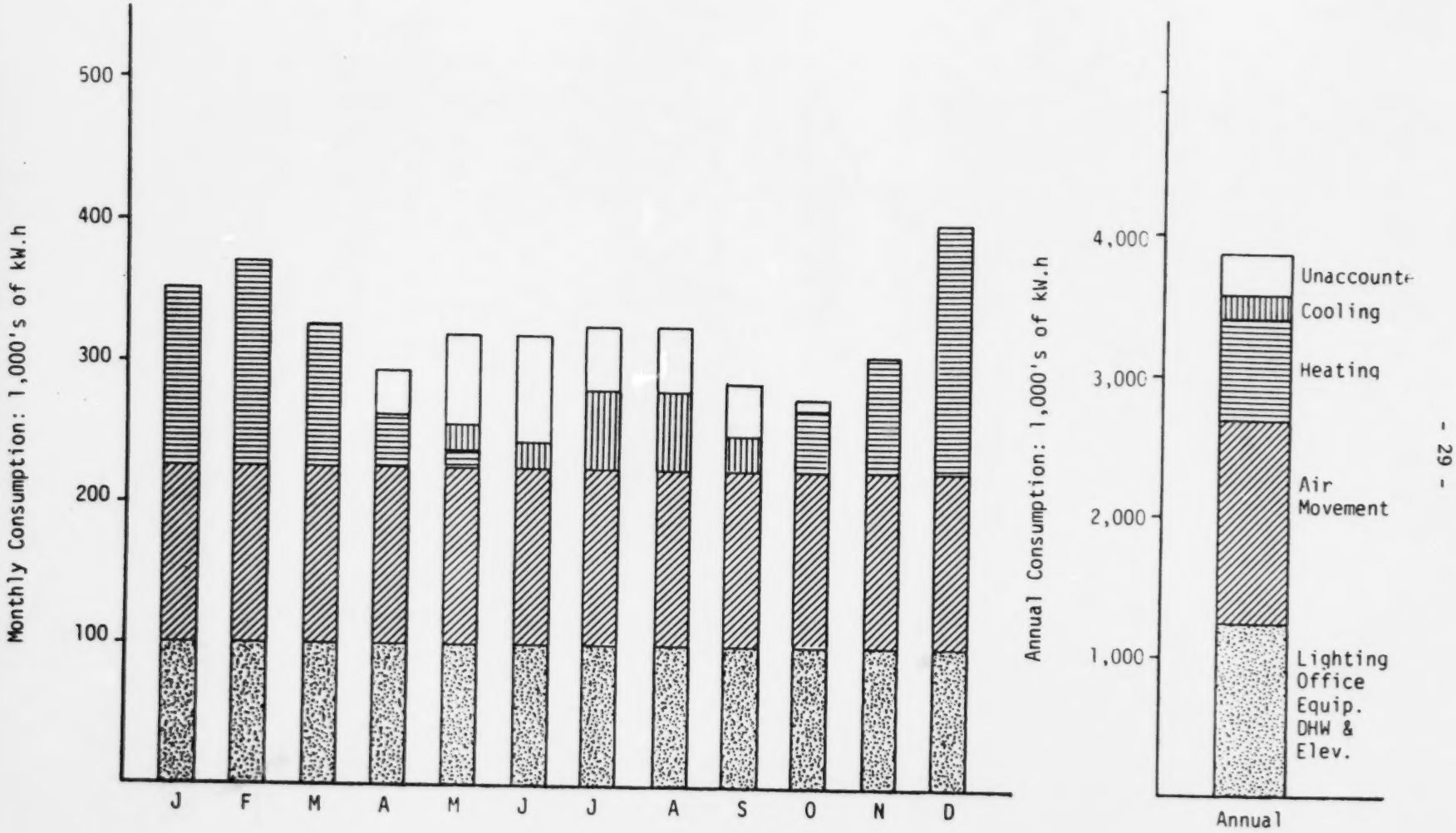
The significant points to note about this graphical presentation are:

- winter and summer peaks

- the large amounts of energy devoted to air movement and lighting, compared to heating

- the small amount of energy devoted to cooling, compared to heating

- some "unnaccounted for" energy showing up during the cooling season months. Conceivably this might be attributed to reheat, but the property manager insists that all reheat coils are disconnected during the cooling season. This

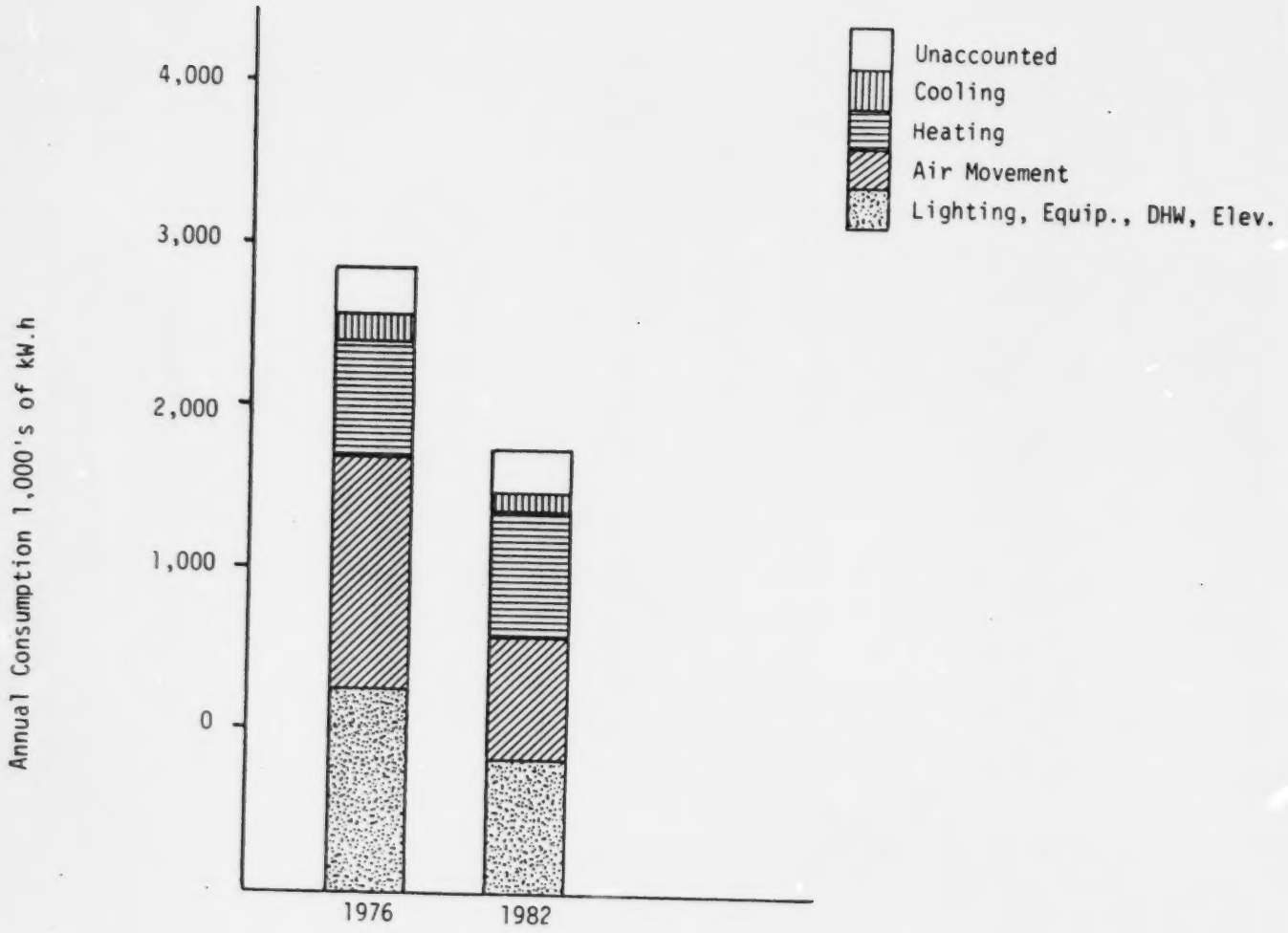


APPORTIONMENT OF ENERGY USE 1976

MARSLAND CENTRE, WATERLOO, ONTARIO

Fig.3-1

ACRES



COMPARISON OF ANNUAL ENERGY USE, 1976/82

MARSLAND CENTRE, WATERLOO, ONTARIO

Fig. 3-4

ACRES

energy therefore remains "unaccounted for" at the present time.

The next exhibit is a similar graphical presentation which demonstrates the effect of the numerous energy conservation measures which were introduced by the property manager between 1976 and the end of 1982.

Note the following:

- overall reduction in energy use of 30% from 3.9 million to 2.7 million kWh
- significant reduction in energy required for lighting, and fans
- an increase in resistance heating energy requirements, (resulting from the reduced lighting load).
- a decrease in cooling energy requirements, (also resulting from the reduced lighting load).

This next exhibit shows the month-by-month comparison of energy use 1976 vs 1982. It will be noted that the conservation measures resulted in reduced consumption each month of the year. In 1982, the winter and summer peaks are still apparent.

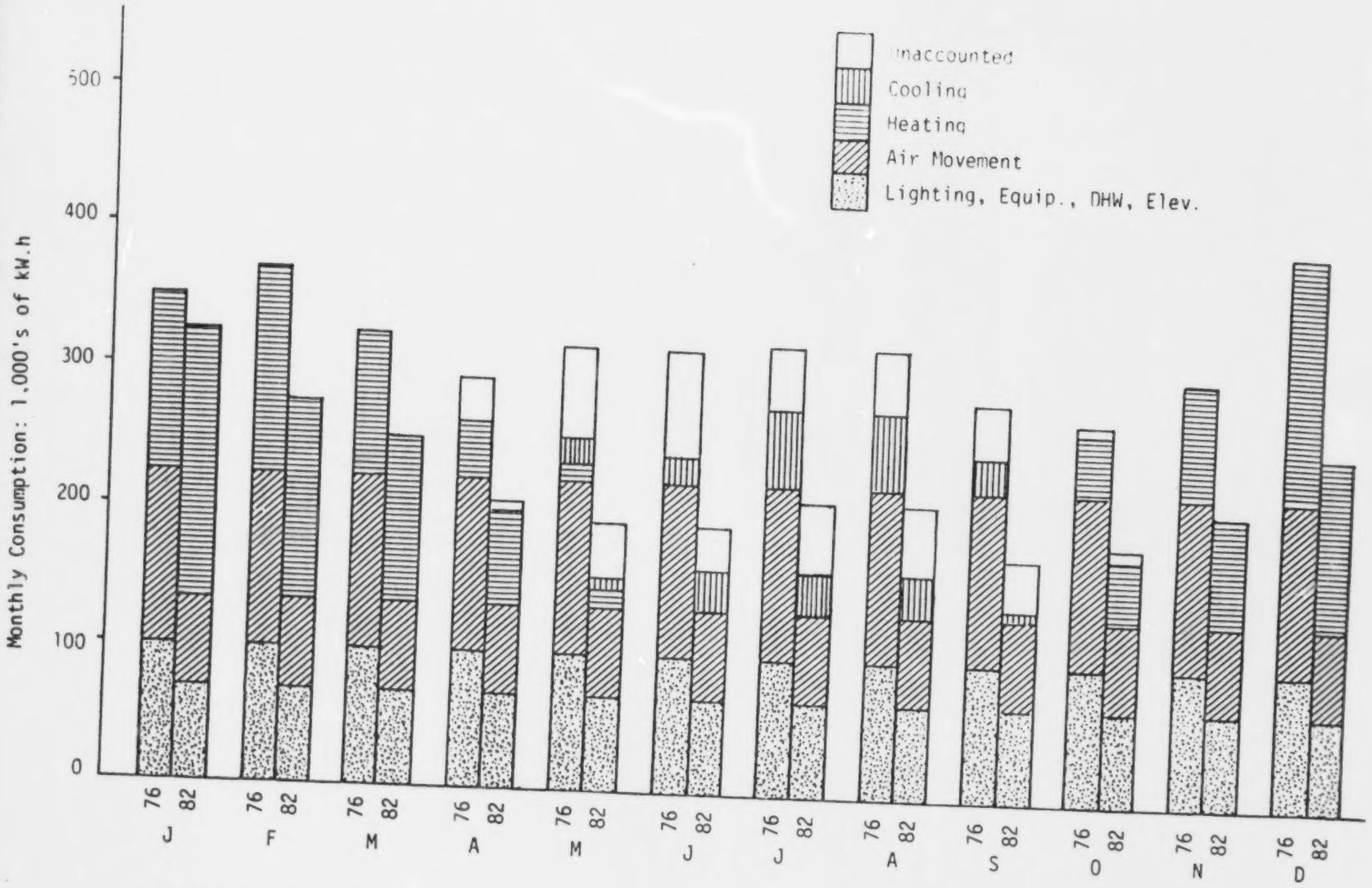
The next exhibit demonstrates the effect that conservation measures have had upon monthly electrical demand, 1976 compared to 1982. Every month shows an improvement, with the overall improvement being 22%.

I now wish to discuss the various energy conservation and demand reduction measures which have been introduced in the Marsland Centre by the property manager, and which have produced the very favorable energy record which the Centre now benefits from.

Elimination of Electric Snow Melting

Electric snow melting cables totalling 25 kW in capacity were provided in the stairs to street level at the four corners of the building podium. In the winter of 1975-76, their use was discontinued not so much as a conservation measure but as a safety measure. Melted ice and snow was running off and refreezing on sidewalk areas increasing the hazard at these areas. Now, snow is manually cleared and ice pellets are applied.

The elimination of electric snow melting was a no-cost conservation measure. The Property Manager estimates the coils were

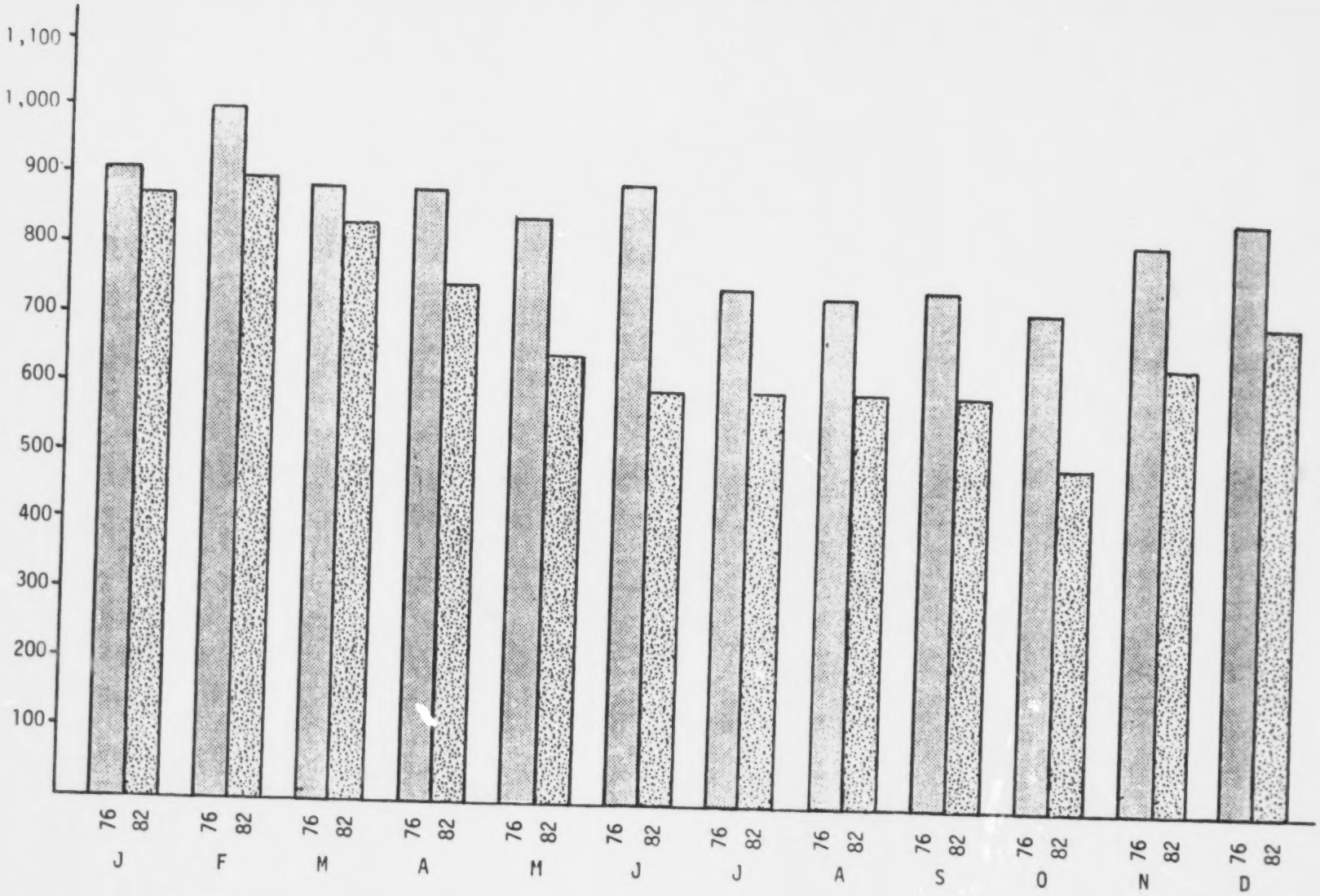


COMPARISON OF MONTHLY ENERGY USE 1976/1982

MARSLAND CENTRE, WATERLOO, ONTARIO

Fig.3-3

ACRES



COMPARISON OF MONTHLY ELECTRICITY DEMAND 1976/82

MARSLAND CENTRE, WATERLOO, ONTARIO

Fig. 3-5

ACRES

on up to 365 hours per winter month prior to their being disconnected, equivalent to 27,000 kW.h per year. The present-day cost of avoided energy use is $800; the potential reduction in electrical demand changes, at present day cost, is a further $200 per year.

Cycling of Washroom Exhaust Fan

In November 1976, a seven-day timer was installed to automatically cycle the 1.5 kW washroom exhaust fan to operate from 7:30 a.m. to 11:00 p.m. weekdays, and for two hours per day Saturdays and Sundays. Prior to this, the fan was allowed to run continuously. The resulting annual energy use avoidance is around 6,000 kW.h. The present-day cost of this timer installation would be about $250.00, and the annual energy cost avoidance $175.00.

Partial Elimination of Supply Air Preheat

The main perimeter supply air systems incorporate electric resistance preheaters arranged to come on in three stages corresponding to reduced outside air temperatures. Now, as a means of limiting electrical demand, these preheaters are timer-controlled to operate only between midnight and 6:00 a.m. on Monday mornings in winter. Their operation follows the weekend-long fan shutdown period during which time building temperature has been allowed to drop. The length of time they are permitted to operate is determined by the Property Manager who bases his judgment on weekend weather forecasts. This measure was introduced in 1976.

The total connected load of the preheaters is 210 kW. By ensuring that they do not operate past 6:00 a.m., a potential 210 kW of additional demand load is avoided, during the winter months, having a present day value of $575 per month. The present day cost of the timer control installation is about $1,200.

Cycling of Main Air Handlers

In April 1977, an automatic timer was introduced to cycle the main air handlers (and all associated and interlocked equipment such as pumps, chiller, and cooling tower) in coordination with building occupancy. The fan systems now operate from 7:00 a.m. to midnight weekdays, with earlier startup on Mondays to pick up load following weekend shutdown. (The reason for running to midnight is that City and Regional Council meetings on weekday evenings often run very late, necessitating running all systems to midnight to ensure that these areas are properly served.) During extremely cold or

warm weather conditions, the systems will be run on weekends to prevent inside conditions from departing too far from normal.

The introduction of fan cycling has resulted in an annual net reduction in electric power consumption estimated at 535,000 kW.h. The present-day value of this avoided energy use is $15,800.00. The current value of the retrofit is $2,000.

Minimizing Simultaneous Heating and Cooling

In August 1979, the Property manager had installed four switches which, through relays, can "kill" electric power to the in-duct secondary (reheat) heaters (776 kW connected load) throughout the building. With these switches, the Property Manager prevents "reheating" of chilled air during the cooling season. He also uses these switches to prevent reheating in winter whenever return air temperature is observed to be at 23°C or above.

The present day cost of this installation is $400. The cost avoidance value of the installation cannot be rationally estimated because power may be "killed" when the coils are already off due to action of the local thermostats. However, the Property Manager is secure in the knowledge that reheat cannot be wastefully applied due to occupant "fiddling" with thermostats whenever he has actuated the "kill" switches. A further benefit of this change is the potential reduction in demand charges which the installation affords.

Chiller Capacity Control

The 300-ton centrifugal chiller is equipped with a manual capacity control which can be used to limit output down to 40 percent of rated capacity. The Property Manager and/or his building operator manipulate the capacity control in response to weather conditions, thus providing manual reset of chilled water supply temperature relative to cooling demands. Chilled water supply temperature is varied between 5.5°C and 7.8°C (nominal design chilled water supply temperatures is 4.4°C). By this means, chiller power demand and consumption is kept to the minimum necessary to produce the desired results.

This is a no-cost conservation measure since the chilled water temperature is being reset manually by existing operating personnel. It is estimated that this measure contributes an annual energy use avoidance of 17,000 kW.h, worth, at present day rates, $500.00.

Ventilation Air Control

All main air handlers are equipped to mix outdoor air with return air for ventilation purposes. In winter, the Property Manager manually closes all outside air dampers in the periphery supply units, and resets the minimum O/A damper setting of the mezzanine unit to achieve a mixed air temperature of 18.3°C. As a result, the bulk of ventilation air is now introduced through the interior supply unit only, and the total fresh air quantity introduced into the building is much reduced below former levels, i.e. from 15 percent of total air circulated to (estimated) 7 percent. The resultant saving in energy consumption for outside air heating is estimated to be 60,000 kW.h, worth $1,800.00 at today's rates.

Temperature Swings

In winter, space temperature is observed to rise during weekdays without the addition of electric heat. This is obviously due to the combination of internal and solar heat gain during the work day. The Property Manager permits the return air temperature to rise within reason; the result being that the additional heat stored in the structure causes less energy to be consumed during pickup load the following day. This is a form of "dead-band" thermostatic control. Insufficient data exists to permit a rational estimate of the magnitude of energy savings which this measure has contributed.

Delamping

Between 1978 and 1981, extensive building delamping has taken place. Throughout the building (with the exception of one of the building tenants which occupies three of the floors), four tube fluorescent fixtures have been delamped to two lamps per fixture. These modifications were done using existing operating staff during regular hours, hence this measure was implemented at no cost. In addition, as tube burnouts occurred, the 40-watt tubes were replaced with 35-watt tubes. Also, exterior lighting has been substantially reduced. Tenant cooperation has been solicited to turn off unneeded lighting. Night cleaning staff cooperates by illuminating only those portions of the building in which they are working.

As a result of the delamping program, power for lighting has been reduced by 390,000 kW.h per year. The reduced lighting levels result in lower cooling requirements in summer, but increased heating requirements in winter. The net reduction from delamping is estimated to be 323,000 kW.h per year having a present-day value of $9,500.00.

Reflective Window Film

In April of 1980, reflective window film was applied to the interior surface of all south and west facing windows at a cost of $7,850. The Property Manager noted that the load on the chiller was reduced as a result of this measure (no figures on the load reduction are available). The computer analysis indicates a reduction in annual power requirements for cooling of 6,000 kW.h worth $180.00 at today's power rates. The reduction in solar energy heat input to the building in winter is claimed to be offset by the reduced transmission heat losses attributable to the film's reputed effect of increasing resistance to heat flow.

Reduction of Exterior Lighting

As designed, the Marsland Centre incorporated extensive exterior perimeter lighting for visual effect purposes. This lighting has been almost eliminated in the interests of energy conservation. After-hours interior lighting in the ground floor offices and lobby provides sufficient spill lighting for illuminating the adjacent exterior podium area.

The few exterior lights and signs which do remain on at night are controlled by a existing time clock to prevent operation throughout the night.

The implementation of this no-cost measure reduced annual energy consumption by approximately 70,000 kW.h, worth $2,000.00 at today's power rates.

Reduction in Water Heating

The office floors of the building are served by two electric water heaters, each 10 kW capacity. It was found that one heater would serve the area adequately. The second heater was disconnected to ensure it would not cause any increase in monthly electrical demand. The annual demand cost avoidance, at the present rate, is up to $330.00.

Recommendations

The various energy conserving features which were incorporated into the original design of the Marsland Centre, and the additional measures which have been introduced by the Property Manager since 1976 are all worthy of consideration by building designers and owners. A recapitulation of these features and measures follows.

Recommendations for New Construction

(a) Provide wall and roof insulation. The optimum thickness of insulation can be determined by energy analysis and cost/benefit analysis.

(b) Provide a low fenestration/opaque wall ratio to minimize winter heat loss and summer heat gain through the transparent glazed areas.

(c) Use insulating window units, complete with tinting and/or reflective coatings. The optimum selection can be facilitated by energy analysis and cost-benefit analysis.

(d) Reclaim energy from waste streams leaving the building.

(e) Building mechanical systems and temperature control systems should include the following design features

- an "economizer" cycle in the air-side temperature control systems, i.e. provide for "free cooling" using outside air when conditions permit
- automatic duty cycling of mechanical equipment to match occupancy schedules
- night and weekend temperature set-back
- minimum outside air consistent with satisfying ventilation codes
- zero outside air when supply air systems must operate during unoccupied hours
- dead-band thermostatic control in which neither mechanical heating or cooling can occur during the temperature swings between the upper and lower dead-band range limits
- chilled water temperature reset in response to outside air temperature
- avoid supply air system types which rely on simultaneous heating and cooling to achieve controlled conditions, e.g. terminal reheat and dual duct systems

(f) Do not over-illuminate interior areas.

(g) Provide minimum exterior lighting consistent with safety and security requirements, and necessary advertising and feature lighting requirements. Provide timer control of exterior lighting where feasible.

(h) Consider the installation of demand limiting controls to prevent excessive electrical demand charges. Loads such as water heaters, secondary fan systems, and electric preheaters can be delayed from operating in order to limit demand.

Recommendations for Retrofits
and/or Operational Improvements

The specific retrofits and operational improvements which have been implemented at the Marsland Centre are unique to that building's design and operating parameters. Others may be able to adapt them directly to their own situation due to similarities in construction, systems, and occupancy. General recommendations which emerge from the Marsland Centre study are

(a) Provide for automatic cycling of mechanical equipment to match occupancy requirements.

(b) Delamp (including ballast disconnection) where over-illumination exists. Consider reducing area illumination in favor of local task lighting which requires less energy.

(c) If snow melting cannot be eliminated, provide for automatic time-limited operation to ensure it is not forgotten and left on.

(d) Consider automatic electric load-shedding controls to control maximum electrical demand. Use manual load shedding if automatic control cannot be justified.

(e) If feasible, reclaim energy from waste streams such as warm exhaust. (A general rule of thumb which has emerged is that exhaust volumes over 472 l/s at 93°C [100 cfm at 200°F] to 2,360 l/s at 21°C [5,000 cfm at 70°C] are most easily justified.)

(f) Reduce minimum outside air settings to levels consistent with minimum ventilation code requirements and occupant comfort.

(g) Implement temperature control modifications

- dead-band operation

- minimize or eliminate reheating

- night set-back of temperature in winter

- zero outside air during quite hours

- chilled water temperature reset

(h) Reduce exterior lighting.

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE REVENUE BUILDING
STE. FOY, QUÉ.

by

Christian R. Roy, P.Eng.
Les Consultants CRS Inc.
Laval, Qué.

crs inc.
experts-consultants
mécanique • électricité • énergie

REPORT ON AN ENERGY EFFICIENT OFFICE BUILDING BY CHRISTIAN R. ROY OF LES CONSULTANTS CRS INC.

"THE REVENUE BUILDING IN STE. FOY, QUEBEC"

IT IS A GREAT HONOUR FOR ME TO HAVE THIS OPPORTUNITY TO ADDRESS THE PRESTIGIOUS AND MOST COMPETENT AUDIENCE GATHERED HERE TODAY. IT IS ALSO A PLEASURE FOR ME TO PRESENT THE ACHIEVEMENTS OF FELLOW DESIGNERS AND WISE BUILDING OPERATORS IN PRODUCING A BUILDING THAT EFFECTIVELY OPERATES WITH A SENSIBLE LOW ENERGY UTILIZATION FACTOR.

MY EXPOSÉ WILL COVER:

- FIRST, A SHORT DESCRIPTION OF THE BUILDING ITSELF AND OF THE MOST SIGNIFICANT OF ITS ENERGY SAVING CHARACTERISTICS.

- SECOND, A REVIEW OF ITS ENERGY EFFICIENCY.

IN THE COURSE OF OUR STUDY, WE SET UP THE ACTUAL ENERGY AUDIT OF THE BUILDING IN RELATION TO THE WAY THE BUILDING IS OPERATED.

OUR METHOD OF ANALYSIS INCLUDED THE LOAD CALCULATIONS AND ENERGY COMPUTATIONS MADE ACCORDING TO THE DEGREE-HOUR METHOD, OR DEGREE-BIN METHOD. NO DYNAMIC ANALYSIS SIMULATION WAS MADE, BUT WE WERE ABLE TO RELATE OUR COMPUTATIONS TO THE ACTUAL PERFORMANCE OF THE BUILDING.

THIRD, A LIST OF THE FACTORS WHICH CONTRIBUTED TO THE ENERGY EFFICIENCY OF THE BUILDING.

- FINALLY, WE WILL HAVE A SHORT DISCUSSION ON SOME PECULIAR ASPECTS OF THE DESIGN OF THIS BUILDING.

FOR INSTANCE, WE WILL HAVE A LOOK AT THE ENERGY PUMPING EFFICIENCY OF THE UNITARY WATER TO AIR HEAT PUMP SYSTEM.

PART I

THE REVENUE BUILDING IS LOCATED IN STE.FOY, A SUBURB OF QUEBEC CITY. IT WAS COMPLETED IN MAY 1979 ACCORDING TO PLANS PREPARED BY GAUTHIER, GUITE & ROY, ARCHITECTS, AND PAQUET, DUTIL, MECHANICAL ENGINEERS. IT IS OWNED BY L'INDUSTRIELLE, A LIFE INSURANCE COMPANY AND OCCUPIED ENTIRELY BY THE QUEBEC DEPARTMENT OF REVENUE.

THE BUILDING ITSELF IS 6 STOREYS HIGH OVER TWO UNDERGROUND FLOORS OF GARAGE AREA. ON THE GROUND FLOOR, THE MALL INCLUDES A COMMERCIAL AREA, WHILE THE FIVE UPPER FLOORS ARE USED EXCLUSIVELY FOR OFFICE SPACE.

EXCLUDING THE GARAGE, THE BUILDING'S GROSS AREA IS 83 847 SQUARE METERS.

THE SKETCH NO. 1 SHOWS A TYPICAL FLOOR.

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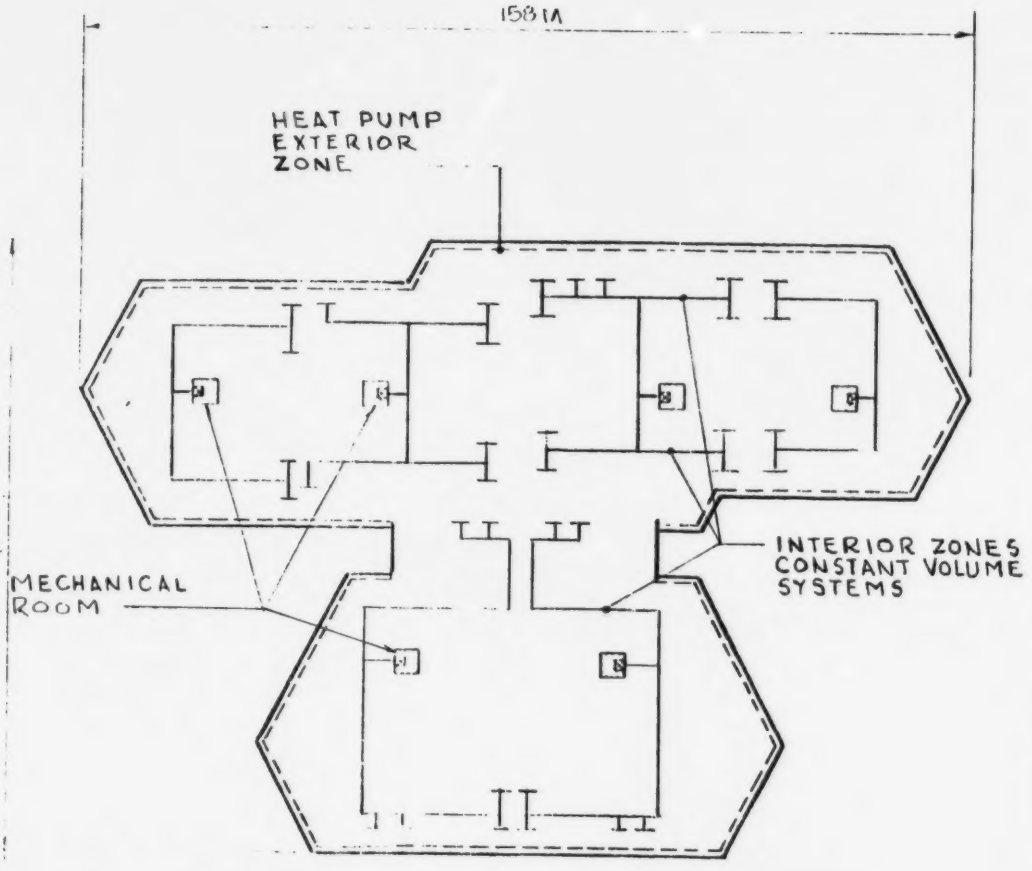
SKETCH NO. 1



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STE-FOY REVENUE BUILDING
TYPICAL FLOOR
N.D. 82-038-000 APRIL 1983

ON SKETCH NO. 2, WE CAN SEE THE TYPICAL CONSTRUCTION OF THE WALLS. A REFLECTING GLASS PLATE ENCLOSES THE OVERALL BUILDING, WINDOWS ARE THERMOS DOUBLE-PLATE GLASS, WHILE THE WALL IS MADE OF PREFABRICATED INSULATED METAL PANELS.

WE WILL COMMENT LATER ON THE USE OF REFLECTING GLASS.

TABLE 1.1 SHOWS THE DIFFERENT GLAZING AREAS ACCORDING TO ORIENTATION.

TABLE 1.1

BUILDING SHELL COMPONENT AREAS (M^2)

GLAZING								WALLS	SKYLIGHTS	ROOFS
N	N.E.	E	S.E.	S	S.W.	W	N.W.			
[illegible]	160	635	110	905	1395	945	110	7230	75	13 270

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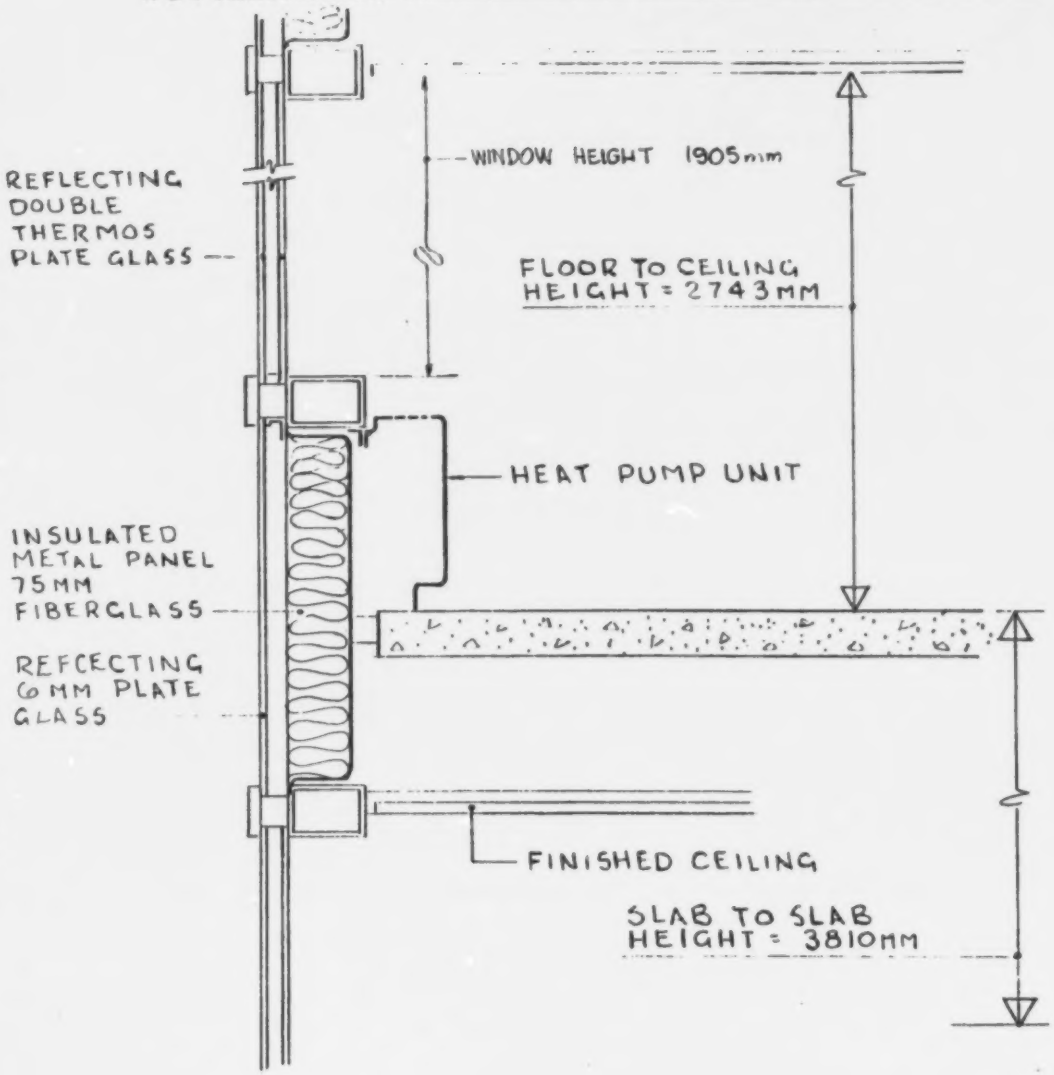
SKETCH NO. 2


WINDOW HEIGHT 1905mm
REFLECTING DOUBLE THERMOS PLATE GLASS
FLOOR TO CEILING HEIGHT = 2743MM
HEAT PUMP UNIT
INSULATED METAL PANEL 75MM FIBERGLASS
REFCECTING 6MM PLATE GLASS
FINISHED CEILING
SLAB TO SLAB HEIGHT = 3810MM

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STE-FOY REVENUE BUILDING
DETAIL-WALL CONSTRUCTION
N.D. 82-098-000 APRIL 1983

TABLE 1.2 SHOWS THE VARIOUS HEAT RESISTANCE FACTORS AND HEAT LOSS FACTORS.

THE OVERALL FENESTRATION FACTOR IS 46%, AN ABOVE AVERAGE FIGURE, NONETHELESS TYPICAL OF CURTAIN-WALL BUILDINGS.

TABLE 1.2

CHARACTERISTICS OF SHELL COMPONENTS

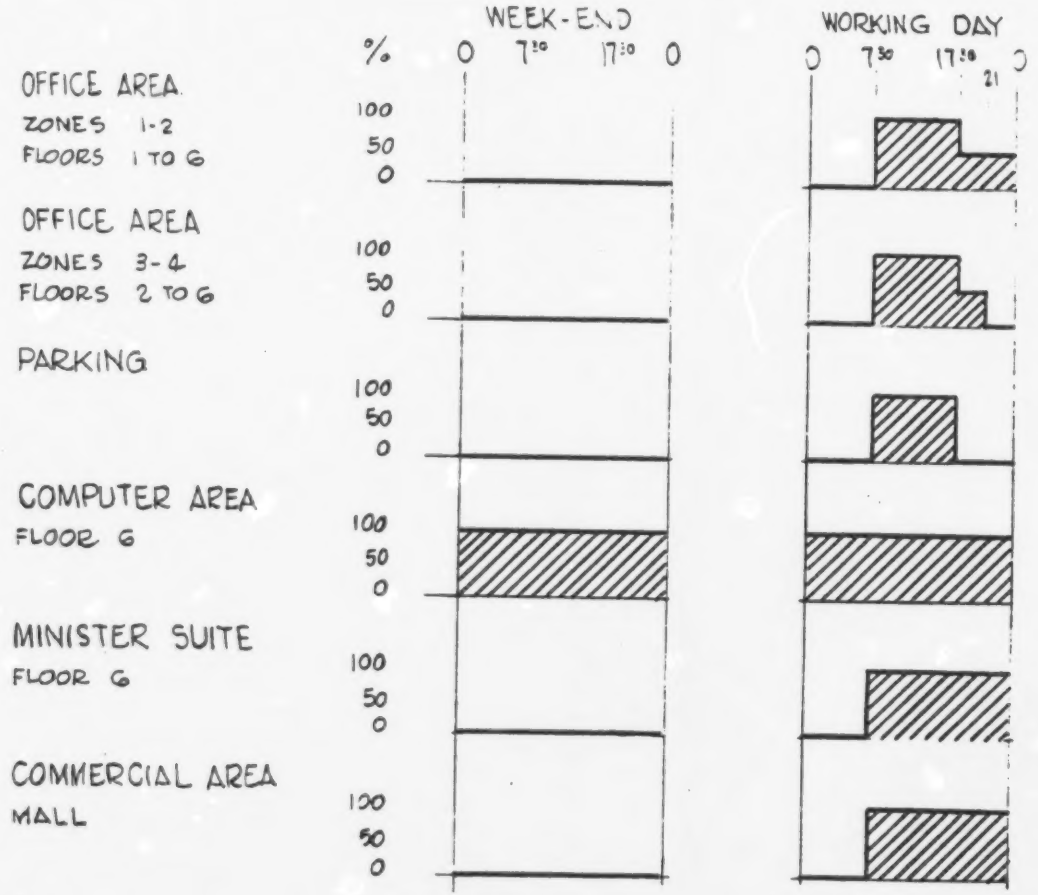
COMPONENTS	CHARACTERISTICS	USI FACTOR	HEAT LOSS
Wall	Reflecting hardened glass 76mm Fiberglas insulation Galvanized steel sheet	0.52	25W/m²
Enclosed Court	4,76mm Aluminium panel 76 mm Fiberglas insulation Galvanized Steel Sheet	0.52	25W/m²
Sealed window unit	Reflecting thermopane	2.84	135W/m²
Roof	Membrane 76 mm Rigid insulation	0.34	16W/m²
Entrances infiltration	Single doors Hardened glass & vestibule	120 l/s/m²	7275W/m²

OVERALL FENESTRATION COEFFICIENT: 46%

THE BUILDING IS OCCUPIED 260 DAYS PER YEAR ON AN AVERAGE BASIS OF 10 HOURS PER DAY. THERE ARE EXCEPTIONS SUCH AS THE COMPUTER SERVICES WHICH ARE IN OPERATION ON A CONTINUOUS BASIS, AND THE MINISTERIAL SUITE WHICH CAN BE USED AT ANY TIME DURING THE WORKING DAYS.

TABLE NO. 1.3 WHICH SHOWS THE LIGHTING SCHEDULE ACCORDING TO DAYS AND OCCUPATION, ILLUSTRATES THE UTILIZATION PROFILE OF THE DIFFERENT AREAS OF THE BUILDING.

LIGHTING SCHEDULE IN EFFECT ON NOVEMBER 1ST 1981



NOTE : 0% MEANS MINIMUM (EMERGENCY) LIGHTING.

TABLE 1.3

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THE PERMANENT POPULATION OF THE BUILDING IS 2800 PEOPLE, TO WHICH WE MUST ADD A FLOATING POPULATION OF ABOUT 500 VISITORS. IN 1984, WHEN THE BUILDING IS FULLY OCCUPIED, THESE FIGURES WILL BE INCREASED BY 800 PEOPLE.

MAINTENANCE IS CARRIED OUT BETWEEN 6:00 P.M. TO 1:00 A.M., WITH AN AVERAGE NIGHT POPULATION OF 20 PEOPLE : COMPUTER OPERATORS, MECHANICAL SURVEILLANCE AS WELL AS SECURITY PERSONNEL.

THE INDOOR LIGHTING SYSTEM USES STANDARD 40W TUBE FLUORESCENT FIXTURES HOUSED IN THE COFFER TYPE CEILING.

ORIGINALLY, ONE-TUBE AND TWO-TUBE FIXTURES WERE INSTALLED ALTERNATELY, GIVING A NOMINAL POWER INTENSITY OF 32.1 WATT/SQ.M. OR 3.0 WATT/SQ. FT. LATER ON, THE TWO-TUBE FIXTURES WERE CONVERTED TO ONE-TUBE UNITS, REDUCING THE OVERALL POWER TO 21.4 WATT/SQ. M., STILL MAINTAINING AN ILLUMINATION LEVEL OF 600 LUX, WITHOUT ANY COMPLAINTS FROM THE OCCUPANTS.

EXCEPT FOR A FEW ROOMS WHICH ARE PROVIDED WITH WALL SWITCHES, MOST OF THE LIGHTING NETWORK IS CONTROLLED FROM THE CENTRAL COMPUTER.

THE HEATING, VENTILATION AND AIR CONDITIONING SYSTEMS

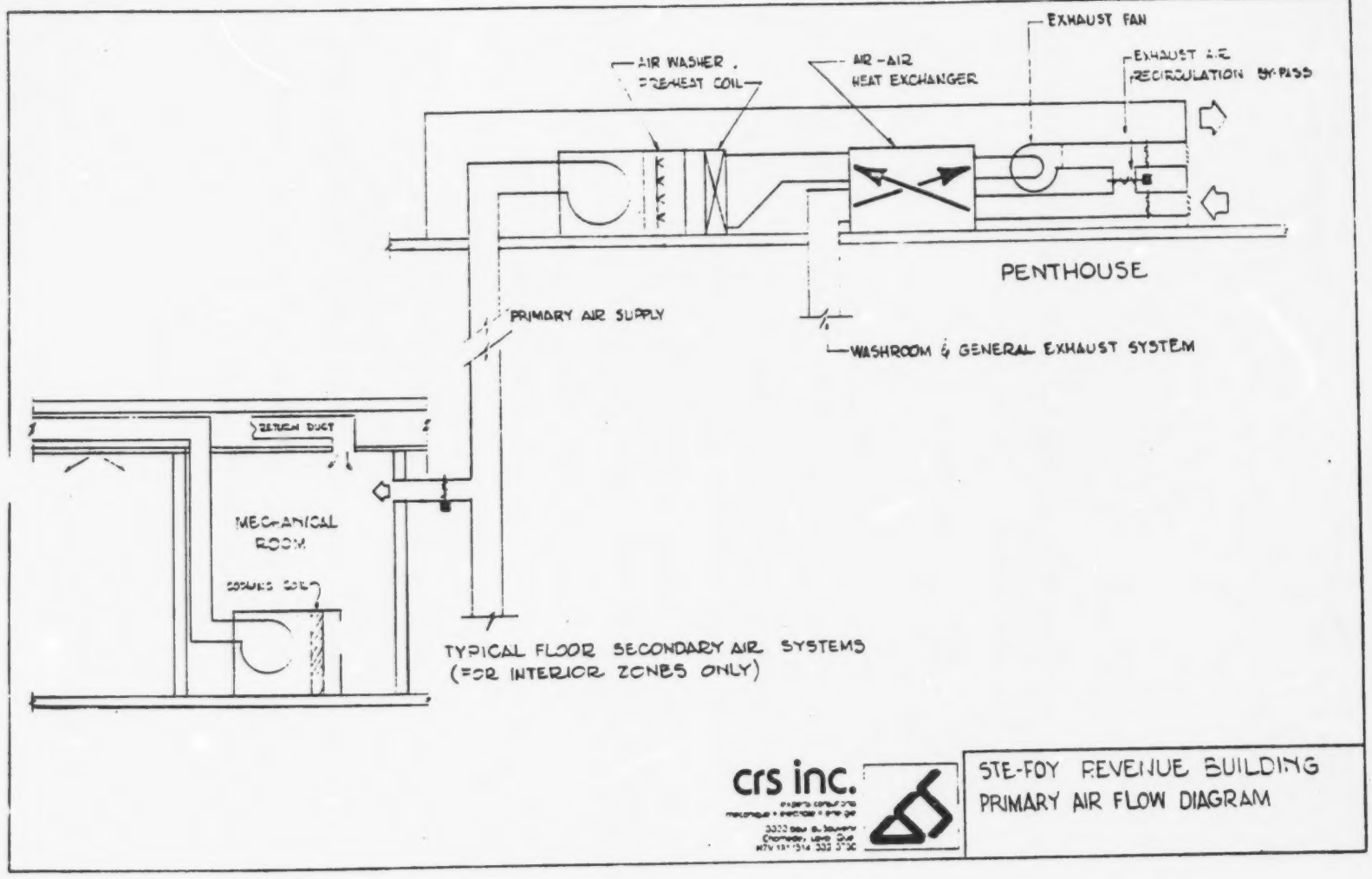
1. THE VENTILATION SYSTEM

AS SEEN ON SKETCH NO. 1, THE INTERIOR ZONES ARE VENTILATED AND COOLED THROUGH A DECENTRALIZED LOW VELOCITY SYSTEM. FIRST OF ALL WE SHALL UNDERLINE THAT PRINCIPLE, A BASIS OF LOW-ENERGY CONSUMPTION SYSTEM FROM THE STANDPOINT OF:

- LOW POWER USE FOR AIR MOVING PURPOSES.

- LOWER IMPACT OF FAN POWER ON AIR CONDITIONING LOADS. IN THE CASE OF A CENTRAL HIGH VELOCITY SYSTEM, FAN POWER CAN REPRESENT AS MUCH AS 25% OF THE TOTAL AIR CONDITIONING LOAD.

SKETCH NO. 3



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STE-FOY REVENUE BUILDING
PRIMARY AIR FLOW DIAGRAM

- RECOVERY OF FAN POWER FOR HEATING PURPOSES AND STORAGE OF ITS ENERGY IN THE THERMAL STORAGE

- FLEXIBILITY OF OPERATING PERIODS. LIMITING THE OPERATION PERIODS OF THE SYSTEM HAS TREMENDOUS EFFECTS ON ENERGY CONSUMPTION. HOWEVER, IN THE CASE OF THE REVENUE BUILDING, THE FANS ARE KEPT IN OPERATION AT NIGHT, THOUGH AT LOW SPEED, FOR SMOKE DETECTION PURPOSES, WHICH COULD BE REALIZED BY OTHER MEANS.

VENTILATION MAKE-UP AIR IS INTRODUCED THROUGH ROOF MOUNTED UNITS, WHERE IT IS HEATED, HUMIDIFIED AND INJECTED IN THE CORE VENTILATION SYSTEMS. AGAIN, WE SHALL UNDERLINE THE MINIMUM FRESH AIR APPROACH VERSUS 100% FREE COOLING WHERE THE EXHAUST AIR ENERGY IS LOST.

FRESH AIR RATE, BASED ON AREA, IS A LOW FIGURE AT 0.5 l/SEC/SQ. M. BASED ON OCCUPANCY IT WILL BE 9.0 l/SEC/PERSON AT FULL OCCUPANCY. THE FRESH AIR FLOW COULD BE REDUCED SUBSTANTIALLY; FOR GOOD ENERGY SAVING PURPOSES, THE RATIO SHOULD MORE LIKELY BE SET AT A LEVEL OF 3.75 l/SEC/PERSON.

UTILITY ROOM AND WASHROOM EXHAUSTS IN THE REVENUE BUILDING ARE COMBINED ON THE ROOF. IN VERY COLD WEATHER, WITH OUTDOOR TEMPERATURES BELOW -18°C, MAKE-UP AIR FLOW IS LIMITED, AND PART OF THE EXHAUST AIR IS BY-PASSED AND RE-INJECTED IN THE FRESH AIR STREAM. ALTHOUGH OF MINIMAL CONSEQUENCE ON TOTAL ENERGY CONSUMPTION, THIS ACTION HAS A SIGNIFICANT IMPACT ON THE HEATING LOAD AND ELECTRICAL DEMANDS OF THE BUILDING, SINCE IT ALLOWS BOTH THE HEAT RECOVERY AND PRE-HEAT SYSTEMS TO OPERATE WITHOUT ANY MAJOR SUPPLEMENTARY HEAT SOURCE.

NEVERTHELESS, WE WOULD NOT RECOMMEND RECIRCULATION OF EXHAUST AIR, WE WOULD RATHER SEE A REDUCED FRESH AIR FLOW.

DURING UNOCCUPIED PERIODS, MAKE-UP AIR AND EXHAUST SYSTEMS ARE STOPPED, AGAIN A VERY EFFICIENT ENERGY CONSERVATION METHOD.

THE MAKE-UP AIR SYSTEM INCLUDES A STATIC TYPE AIR-TO-AIR HEAT EXCHANGER, A PRE-HEAT GLYCOL COIL, DRAWING ITS ENERGY FROM THE HEAT GENERATED IN THE BUILDING, AND CENTRAL HUMIDIFICATION WITH AIR WASHER. MAKE-UP IS THEN PRE-HEATED AT 20°C AND HUMIDIFIED AT SATURATION AT 7°C, THUS MAINTAINING IN THE BUILDING A HUMIDITY LEVEL OF OVER 35% RH. THE AIR WASHER PROVIDES A "FREE COOLING" EFFECT WHEN THE MAKE-UP AIR IS MIXED WITH THE RETURN AIR. HOWEVER, THIS "FREE COOLING" EFFECT COULD BE INCREASED IF THE MAKE-UP AIR WAS NOT HEATED AND HUMIDIFIED CENTRALLY. WE WOULD THEN LOSE THE COOLING REJECTION HEAT, BUT THIS RECOVERED HEAT IS ACTUALLY USEFUL ONLY WHEN THE BUILDING IS NEGATIVE IN ITS 24-HOUR CYCLE ENERGY BALANCE, SAY DURING A FEW HOURS WHEN THE OUTSIDE TEMPERATURE IS BELOW -22°C.

TABLE 1.4 - EVALUATION OF THE NET HEATING LOAD (kW)

	DAY TIME				NIGHT TIME			
Outside temperature	-28°C	-22C	-18°C	-7°C	-28°C	-22°C	-18°C	-7°C
Losses								
Shell heating	2360	2040	1840	1310	2360	2040	1840	1310
Fresh Air Heating & humidifying	2200	1910	1710	1220	-	-	-	-
TOTAL LOSSES	4560	3950	3550	2530	2360	2040	1840	1310
Recovered internal gains								
Lighting & people services	1490	1490	1490	1490	150	150	150	150
Computers	555	555	555	555	555	555	555	555
Water chiller	375	375	375	375	-	-	-	-
Exhaust air heat recovery	1020	885	770	550	-	-	-	-
Motor fan & pumps	715	715	715	715	285	285	285	285
Heat pump compressors	660	570	510	365	660	570	510	365
TOTAL GAINS	4815	4590	4415	4050	1650	1590	1500	1355
Net Balance								
Day excess night deficit	255	640	865	1520	710	500	340	45
Energy sent to the thermal reserve kWh	2550	6400	8650	15200	9940	7000	4760	630

24 hour Cycle Energy Balance

At -28°C = 7390 kWh deficit

At -18°C = 3890 kWh surplus

Temperature variation of the thermal reserve -22°C: 4°C

AGAIN, IF WE LOOK AT THE PROFITABILITY OF THE MAKE-UP AIR HEAT EXCHANGER, THE FUNCTION OF THIS PIECE OF EQUIPMENT HAS TO BE ANALYSED IN REGARD TO THE NET ENERGY BALANCE OF THE BUILDING. WHEN THE BUILDING IS IN EXCESS OF ENERGY, THIS RECOVERED HEAT INCREASES THE COOLING LOAD. ACTUALLY, THE PROFITABILITY OF THE RECUPERATOR IS REACHED DURING VERY FEW HOURS, (A TOTAL PERIOD OF 50 HOURS PER YEAR DURING THE NORMAL OCCUPANCY OF THE BUILDING).

A FEW WORDS CONCERNING THE GARAGE VENTILATION. NEITHER THE VENTILATION AIR NOR THE GARAGES ARE HEATED. MOREOVER, THE VENTILATION SYSTEMS ARE OPERATED ON DEMAND THROUGH CARBON MONOXYDE CONCENTRATION DETECTORS. WE CANNOT IMAGINE A MORE EFFICIENT DESIGN, EXCEPT FOR THE MODIFICATIONS BROUGHT TO IT AFTERWARDS, TO CIRCULATE IN THE GARAGE, EXHAUST AIR FROM THE MECHANICAL ROOMS. THIS ADDED CIRCULATION AIR PROVIDES TWO FUNCTIONS:

- FIRST, A MINIMAL HEATING OF THE GARAGE

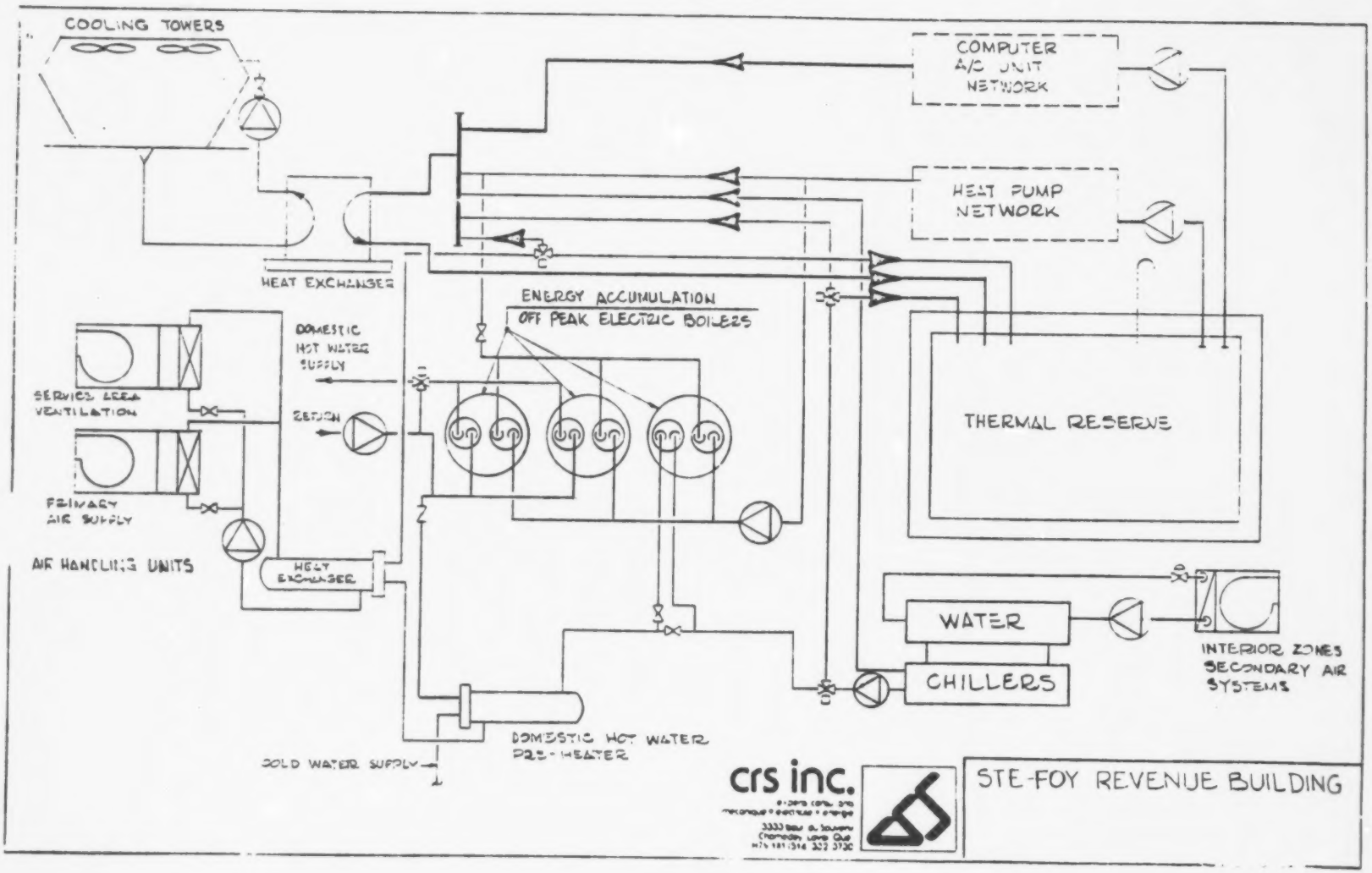
- SECOND, A CONSTANT MINIMAL VENTILATION, REDUCING THE CARBON MONOXYDE CONCENTRATION AND MINIMIZING THE FAN OPERATION.

2. THE HEATING AND REFRIGERATION SYSTEMS

PERIMETER HEATING AND COOLING ARE PROVIDED BY UNITARY WATER TO AIR HEAT PUMPS. SEVEN HUNDRED AND EIGHTY (780) ENERCON WALL TYPE HEAT PUMPS ARE CONNECTED TO A RUN-AROUND WATER LOOP. IN ADDITION COMPUTER AIR CONDITIONING IS ACHIEVED THROUGH 14 LIEBERT WATER-COOLED UNITS CONNECTED TO A SEPARATE LOOP.

INTERIOR ZONES AIR CONDITIONING HEAT REJECTION IS INJECTED IN THE WATER CIRCUIT, WHICH ALSO PROVIDES THE PRE-HEAT COILS AND DOMESTIC PRE-HEATERS WITH RECOVERED ENERGY.

SKETCH NO. 4


COOLING TOWERS
COMPUTER A/C UNIT NETWORK
HEAT PUMP NETWORK
HEAT EXCHANGER
ENERGY ACCUMULATION
OFF PEAK ELECTRIC BOILERS
DOMESTIC HOT WATER SUPPLY
RETURN
SERVICE AREA VENTILATION
PRIMARY AIR SUPPLY
AIR HANDLING UNITS
HEAT EXCHANGER
THERMAL RESERVE
WATER
CHILLERS
INTERIOR ZONES SECONDARY AIR SYSTEMS
DOMESTIC HOT WATER PRE-HEATER
COLD WATER SUPPLY
crs inc.
STE-FOY REVENUE BUILDING

TEMPERATURE IN THE RUN-AROUND LOOP IS MAINTAINED BETWEEN 27°C AND 32°C. HEAT IS REJECTED THROUGH ROOF-MOUNTED COOLING TOWERS AND THROUGH A SEPARATE COOLING CIRCUIT TO PREVENT CONTAMINATION OF THE RUN-AROUND LOOP, AND SUPPLEMENTARY HEAT IS INJECTED THROUGH THREE (3) 17 000 LITRE MEGATHERM HOT WATER BOILERS, 480 kW EACH, OPERATING EXCLUSIVELY OFF PEAK.

AN OPEN TYPE THERMAL RESERVE OF 1 325 000 LITRES OF CAPACITY ALLOWS THE ACCUMULATION OF SURPLUS RECOVERED ENERGY, OR OFF-PEAK ELECTRICITY.

THE CENTRAL COOLING PLANT INCLUDES THREE LOW PRESSURE CENTRIFUGAL CHILLERS FOR THE PURPOSE OF AIR CONDITIONING THE INTERIOR ZONES.

IN PRACTICE, ONLY ONE (1) OF THE BOILERS AND ONE (1) OF THE CHILLERS ARE USED IN WINTERTIME.

FUNDAMENTALLY, THE RUN-AROUND HEAT PUMP SYSTEM IS ENERGY EFFICIENT SINCE IT ALLOWS TRANSFER OF HEAT FROM THE CORE OF THE BUILDING, ITS EQUIPMENT POWER AND COMPUTER POWER TO FILL THE NEEDS FOR PERIMETER HEATING. WE WILL SEE LATER, HOWEVER, THAT THIS ENERGY PUMPING FUNCTION IS NOT ACHIEVED IN THE MOST EFFICIENT MANNER.

MOREOVER, THE THERMAL RESERVE AGAIN ALLOWS THE TRANSFER OF HEAT GENERATED IN THE DAY-TIME AND IN EXCESS OF THE INSTANTANEOUS NEEDS, TO THE NIGHT PERIOD WHERE INTERNAL GAINS ARE LOWER AND HEATING NEEDS ACTUALLY OCCUR.

ON TABLE 1.4 WE CAN SEE THAT THE PERIOD WHERE THIS TRANSFER OCCURS AND WHEN IT IS REALLY NEEDED SPREADS OVER THE HOURS WHERE OUTSIDE TEMPERA-TURE IS BELOW $-7^{o}C$ OR 1500 HOURS PER YEAR.

TABLE 1.4 - EVALUATION OF THE NET HEATING LOAD (kW)

	DAY TIME				NIGHT TIME			
Outside temperature	-28°C	-22C	-18°C	-7°C	-28°C	-22°C	-18°C	-7°C
Losses								
Shell heating	2360	2040	1840	1310	2360	2040	1840	1310
Fresh Air Heating & humidifying	2200	1910	1710	1220	-	-	-	-
TOTAL LOSSES	4560	3950	3550	2530	2360	2040	1840	1310
Recovered internal gains								
Lighting & people services	1490	1490	1490	1490	150	150	150	150
Computers	555	555	555	555	555	555	555	555
Water chiller	375	375	375	375	-	-	-	-
Exhaust air heat recovery	1020	885	770	550	-	-	-	-
Motor fans & pumps	715	715	715	715	285	285	285	285
Heat pump compressors	660	570	510	365	660	570	510	365
TOTAL GAINS	4815	4590	4415	4050	1650	1590	1500	1355
Net Balance								
Day excess night deficit	255	640	865	1520	710	500	340	45
Energy sent to the thermal reserve kWh	2550	6400	8650	15200	9940	7000	4760	630

24 hour Cycle Energy Balance

At -28°C 7390 kWh deficit

At -18°C 3390 kWh surplus

Temperature variation of the thermal reserve -22°C: 4°C

THE MECHANICAL SYSTEMS ARE MONITORED BY A CENTRAL COMPUTER, A HONEYWELL DELTA 1000, WHICH SUPERVISES CONDITIONS IN THE BUILDING ON A CONTINUOUS BASIS. THE COMPUTER CONTROLS MAINLY THE LIGHTING AND AIR CONDITIONING SCHEDULES; IT ALSO ACTS AS A DEMAND STABILIZER BY CONTROLLING OFF-PEAK BOILERS AND THROUGH AN ELABORATE PRIORITY SCHEDULE OF UNLOADING, TEMPERATURE RESETS, EQUIPMENT CYCLING, HEATING AND FRESH AIR REDUCTION. TEMPERATURE SET-BACK, OPTIMAL START AND CHILLER OPTIMIZATION ARE OTHER ENERGY CONSERVATION FEATURES OF THE COMPUTER.

AN INTERESTING FUNCTION IS THE TEMPERATURE NIGHT SET-BACK AND ITS EFFECT ON OFFICE BUILDINGS. IN THE REVENUE BUILDING, ALTHOUGH SOME HEAT IS GENERATED DURING THE NIGHT, THE NIGHT SET-BACK ACTUALLY PREVENTS HEATING DURING THE NIGHT.

MOREOVER, ALTHOUGH CIRCULATING PUMPS ARE KEPT RUNNING DURING THE NIGHT, THE ENERGY STORED IN THE THERMAL RESERVE IS NOT DRAWN UPON OR IS DRAINED OUT VERY SLOWLY BY THE ZONES MOST EXPOSED, WHERE THE THERMOSTAT REACHES THE LOW LIMIT. IN ESSENCE, WHAT HAPPENS, AND THIS IS A MAJOR DISADVANTAGE OF THE RUN-AROUND LOOP SYSTEM, IS THAT THE CIRCULATING PUMPS ARE KEPT OPERATING AT FULL FLOW FOR A VERY SMALL HEATING DEMAND. ACTUALLY, THE POWER GENERATED BY THE PUMPS (200 KW), IS PROBABLY ENOUGH TO SUPPLY THAT MINIMAL ENERGY. IN THE CASE OF A RUN-AROUND HEAT PUMP SYSTEM, NIGHT SET-BACK APPEARS INCOMPATIBLE WITH THE EFFICIENT USE OF THERMAL RESERVE.

AT THE REVENUE BUILDING, SENSIBLE SAVINGS WOULD BE OBTAINED BY STOPPING THE CIRCULATING PUMPS OF THE RUN-AROUND LOOP DURING THE NIGHT, AND USING THE ENERGY STORED IN THE THERMAL RESERVE DURING A SHORT PERIOD OF TIME FOR WARM-UP PURPOSES.

ANOTHER PENALIZING ASPECT OF THE RUN-AROUND LOOP IS THE CLOSE TEMPERATURE DIFFERENTIAL THAT MUST BE KEPT ACROSS THE LOOP. THIS CIRCUIT MUST BE SUPPLIED WITH WATER WARMER THAN 27°C. AT THE REVENUE BUILDING, WE NOTICED THAT THE ELECTRICAL BOILERS ARE SOLLICITED AND ACTUALLY PROVIDE ENERGY AT THE WARM-UP, WHILE THEORETICALLY, THE THERMAL RESERVE SHOULD CONTAIN SUFFICIENT ENERGY FOR THE NIGHT HEATING NEEDS (HOWEVER, THIS ELEMENT DOES NOT ADD TO THE ELECTRICAL PEAK, SINCE THE BOILERS ARE POSITIVELY DEMAND-CONTROLLED, AND THE COMPRESSOR MOTORS DEMAND IS SCHEDULED TO TAKE PLACE BEFORE TURNING ON THE LIGHTS).

MOREOVER, THAT SMALL TEMPERATURE DIFFERENTIAL ACROSS THE LOOP, LIMITS THE ENERGY CONTENT CAPACITY OF THE THERMAL RESERVE. INVERSELY, A LARGER RESERVE IS NEEDED FOR A GIVEN ENERGY CAPACITY.

TO SUMMARIZE, THE MOST EFFICIENT WAY TO OPERATE THE RUN-AROUND LOOP AT THE REVENUE BUILDING WOULD INCLUDE:

- LIMITED OPERATION OF THE CIRCULATING PUMPS.

- LARGE TEMPERATURE DIFFERENTIAL ACROSS THE RUN-AROUND LOOP AND THE THERMAL RESERVE AND LESS DEMAND ON THE ELECTRIC BOILERS.

- RAPID WARM-UP WITH THE USE OF THE THERMAL RESERVE, BEFORE TURNING ON THE LIGHTS.

TABLE 1.5 - SUMMARY OF BUILDING DATA

Building gross area without the garages	83 847 m^2
Air conditioned areas: exterior zone	11 890 m^2
interior zone	65 495 m^2
Air conditioning load with original lighting without the computer	4 326 kW
Air conditioning load with reduced lighting without the computer	3 605 kW
Equipment of computer room	675 kW
Cooling units of computer room	410 kW
Water chillers, motors $\times \frac{2 \times 375\ kW}{1 \times 212\ kW}$	962 kW
capacity $\times \frac{2 \times 1582\ kW}{1 \times 791\ kW}$	3 955 kW
Total lighting originally installed	2 460 kW
Reduced lighting	1 600 kW
Individual heat pumps, sensible capacity	1 940 kW
Individual heat pumps, motors	1 110 kW
Fans & pump motors	875 kW
Cooling towers 3 x 35 kW	105 kW
Air compressors 2 x 15 kW	30 kW
Electric boiler 3 x 480 kW off-peak	1 440 kW
Garage fans 20 x 15 kW	300 kW

TABLE 1.5 - CONT'D

Interior zones supply	218 027 l/s
Make-up air (theoretical)	36 600 l/s
(effective) supply at 7°C	28 315 l/s
Garage supply not heated	236 000 l/s
Exhaust, vault + WC recovery 67%, outlet at 2°C	43 415 l/s
Shell heating load	2 350 kW
Fresh air and humidification heating load (28 315 l/s)	2 200 kW
Population	± 2 800 pers.
Domestic hot water by recovery	35°C
Domestic hot water for kitchen	60°C
Number of meals served daily at the cafeteria	350/working day
Room comfort - summer: 50% RH/24°C	
- winter: 35% RH/21°C	
- computer rooms: 21/24°C - 45/50% RH	
Thermal reserve	1 325 000 l

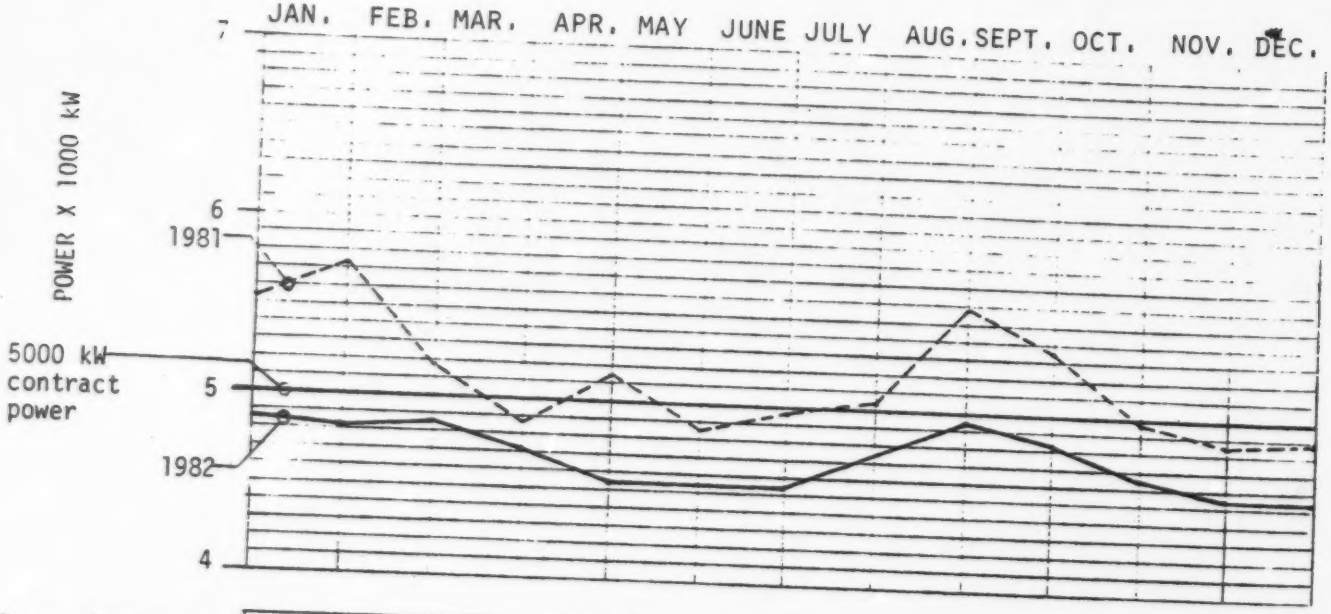
PART II

IN REVIEWING THE ENERGY EFFICIENCY OF THE BUILDING, WE HAVE BEEN ABLE TO ANALYZE THE HISTORICAL CONSUMPTION OF THE TWO PAST YEARS, 1981 AND 1982.

TABLES 2.1 AND 2.2 DETAIL THE OVERALL ELECTRICITY UTILIZATION OF THIS PERIOD, WHILE TABLE 3.3 SUMMARIZES THE MAIN ENERGY CHARACTERISTICS DURING THAT SAME PERIOD.

FROM 1981 TO 1982, THE REDUCTION OF APPROXIMATELY 10% OF THE ANNUAL DEMAND AND CONSUMPTION IS EXPLAINED ESSENTIALLY BY THE PROGRAM OF LIGHTING REDUCTION, IMPLEMENTED GRADUALLY FROM THE SUMMER 1982 TO THE SUMMER 1983. THIS PROGRAM REDUCED THE INITIAL LIGHTING LOAD FROM 2460 kW TO APPROXIMATELY 1600 kW. AT THE END OF 1982, THE UNITARY CONSUMPTION, EXCLUDING THE GARAGE, WAS OF 253.9 kW PER SQUARE METER PER YEAR.

FIG. 2.1 - MONTHLY PEAK DEMAND PROFILE - 1981 - 1982



Power factor		93.9	97.6	97.2	95.6	97.2	97.9	97.0	96.9	96.9	97.1	97.8	97.8
Utilization factor For 1982	%	46.7	53.8	56.0	49.7	47.8	45.8	46.2	48.2	46.0	46.0	47.0	50.0

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PERIOD	NBR OF DAYS	MEASURED kW	MEASURED KVA	MEASURED kWh	CUMULATIVE kWh	POWER FACTOR	UTILIZATION FACTOR %	INVOICED kW CONTRACT 5000	DAILY kWh	ANNUAL CONSUMPTION THOUSAND kWh/kW/YEAR	MONTHLY COST $	CUMULATIVE COST $
Dec. 10 to Jan. 14 1981	35	5472	6004	2 168 800	2 168 800	90.8	52.1	5703	62 537	272.2	68 674.24	68 674.24
Fev. 11	28	5184	5328	1 930 800	4 099 600	97.3	56.5	5184	67 885	295.5	53 011.65	121 685.89
Mar. 11	28	4896	4992	1 924 802	6 014 400	98.1	57.2	5000	68 792	299.5	50 705.57	172 391.46
Apr. 10	30	5136	5232	2 078 400	8 092 800	98.2	57.7	5136	69 289	301.6	56 703.63	229 095.09
May 12	32	4848	5040	1 934 410	10 024 200	96.2	50.0	5000	60 450	263.2	53 292.50	282 868.59
June 13	29	4946	5040	1 826 400	11 853 600	98.1	52.5	5000	62 979	274.2	49 890.02	332 787.61
July 13	33	5040	5232	2 061 600	13 915 200	96.3	52.0	5040	62 472	272.0	56 703.04	389 495.65
Aug. 12	30	5568	5640	1 992 000	15 907 200	98.7	55.3	5568	66 400	289.1	55 655.94	445 151.59
Sept.11	30	5352	5448	1 922 400	17 829 600	98.2	53.4	5352	64 070	278.9	53 642.22	498 293.81
Oct. 13	32	4992	5016	1 886 400	19 716 000	99.5	49.1	5000	58 950	256.6	53 041.82	551 835.63
Nov. 11	29	4848	4992	1 776 400	21 492 400	97.1	51.0	5000	61 255	266.7	48 954.42	600 295.05
Dec. 10	29	4824	5136	1 814 200	23 311 650	93.9	52.2	5000	62 731	273.1	49 786.27	650 581.32
TOTAL	365			23 311 610						278.0 ANNUAL	650 581.32	

TABLE 2.1 - ELECTRICITY DEMAND AND CONSUMPTION CHARACTERISTICS FOR THE YEAR 1981

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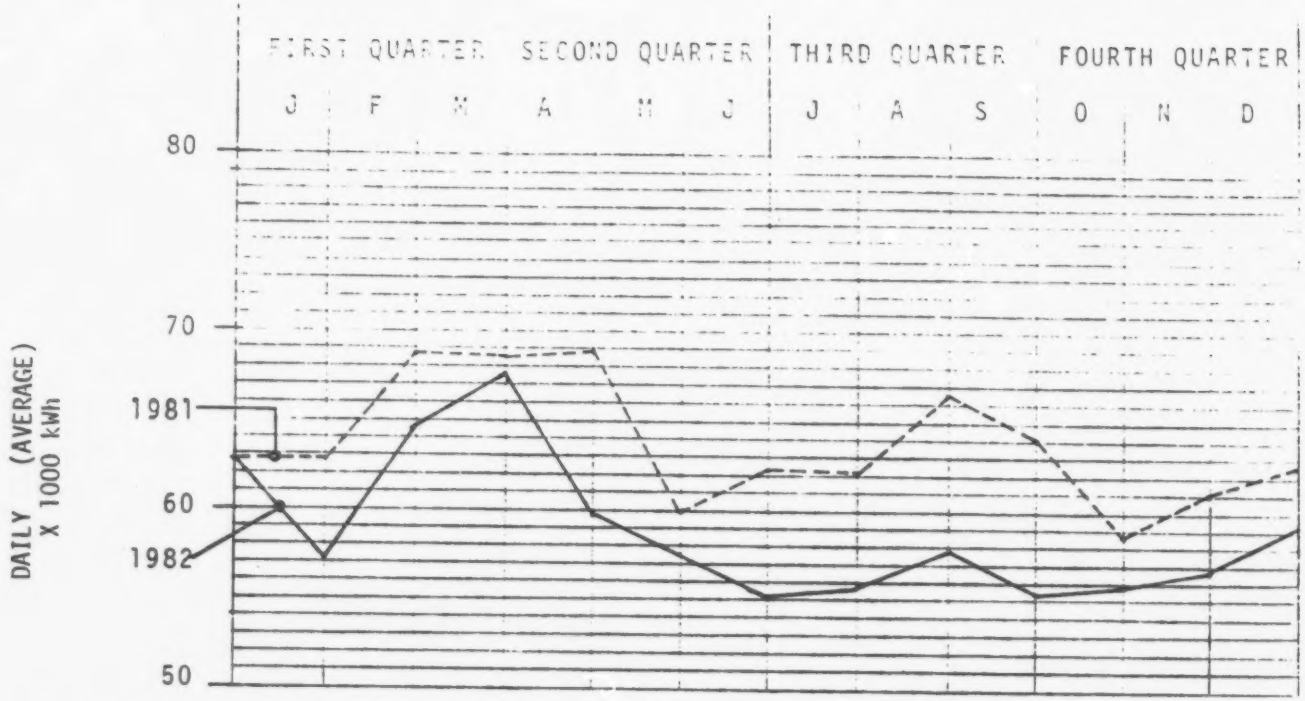

FIG. 2.2 - AVERAGE DAILY ELECTRICAL CONSUMPTION PROFILE

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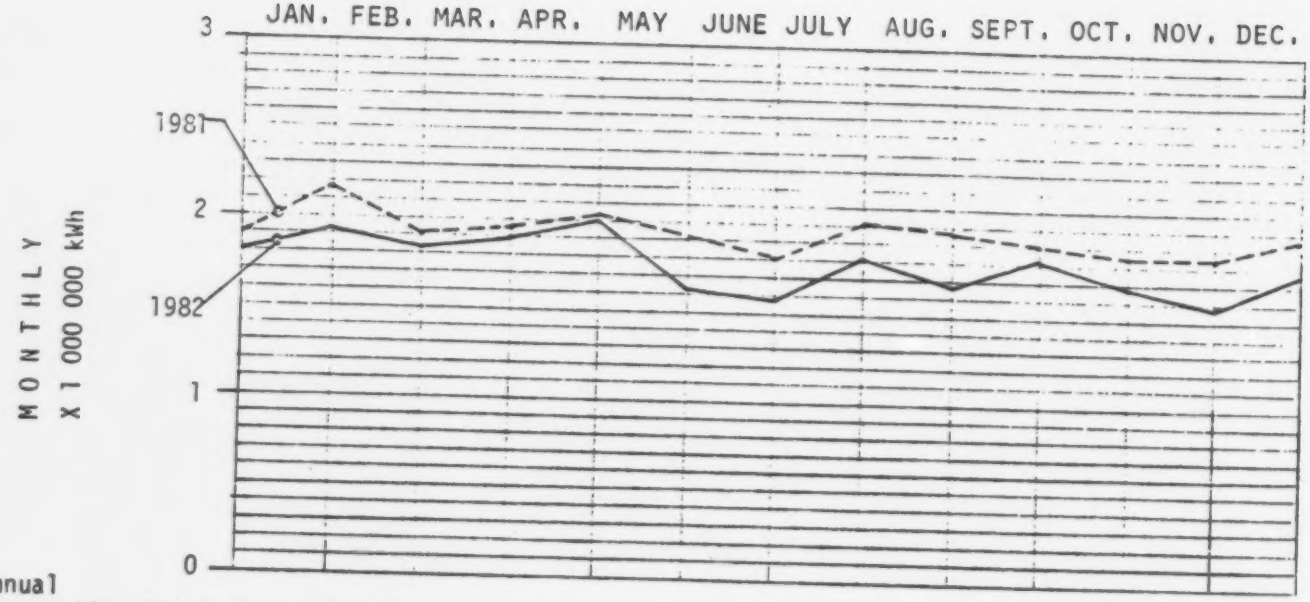
PERIOD	NBR OF DAYS	MEASURED kW	MEASURED kVA	MEASURED kWh	CUMULATIVE kWh	POWER FACTOR	UTILIZATION FACTOR	INVOICED kW CONTRACT 5000	DAILY kWh	ANNUAL CONSUMPTION kWh/MW YEAR x 1000	MONTHLY COST $	CUMULATIVE COST $
Dec. 10 to Jan. 13 1982	34	4776	4834	1 908 000	1 908 000	93.9	46.7	5000	56 117	244.3	58 550.32	58 550.32
Jan. 13 Feb. 10	28	4948	4848	1 810 560	3 718 560	97.6	53.8	5000	64 662	281.6	57 845.01	116 395.33
Mar. 10 Feb. 17	28	4709	4832	1 890 240	5 608 800	97.2	56.0	5000	67 503	293.9	59 411.20	175 806.53
Mar. 10 Apr. 14	35	4521	4503	2 089 560	7 697 360	95.6	49.7	5000	59 684.5	259.8	68 881.40	244 687.93
Apr. 14 May 12	28	4541	4437	1 608 240	9 306 000	97.2	47.8	5000	57 437.1	250.0	58 868.21	303 556.14
May 12 June 10	29	4541	4408	1 595 280	10 901 280	97.9	45.84	5000	55 009.5	239.5	54 408.35	357 964.49
June 10 July 13	33	4752	4653	1 831 260	12 732 540	97.0	46.24	5000	54 490.9	237.2	62 801.27	420 765.76
July 13 Aug. 11	29	4920	4823	1 680 000	14 412 540	96.9	48.2	5000	57 931	252.2	59 592.80	477 358.56
Aug. 11 Sept.13	33	4829	4717	1 826 400	16 238 940	96.9	46.0	5000	55 345.4	240.9	62 706.04	540 064.60
Sept.13 Oct. 13	30	4656	4556	1 670 400	17 909 340	97.1	46.0	5000	55 680	242.4	57 204.60	597 269.20
Oct. 13 Nov. 10	28	4502	4372	1 593 600	19 502 940	97.6	47.0	5000	56 914	247.8	54 076.56	651 345.76
Nov. 10 Dec. 10	30	4512	4384	1 788 000	21 290 940	97.9	50.0	5000	59 600	259.5	59 537.54	710 883.30
TOTAL	365			21 290 940						259.9 ANNUAL	710 883.30	710 883.30

TABLE 2.2- ELECTRICITY DEMAND AND CONSUMPTION CHARACTERISTICS FOR THE YEAR 1982

crs inc.



Annual Consumption index kWh/m² (gross area) For 1982											
244.3	281.5	293.9	259.8	250.0	239.5	237.2	252.2	240.9	242.4	247.8	259.5

FIG. 2.3 - MONTHLY ELECTRICAL CONSUMPTION PROFILE - 1981-1982

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TABLE 2.3 - SUMMARY OF ENERGY CHARACTERISTICS FOR THE REVENUE BUILDING (1981-1982)

	1981	1982
Annual demand	61 104 kW (100%)	55 137 kW (90.2%)
Mean monthly demand	5 092 kW/month	4 595 kW/month
Annual consumption	23 311 610 kWh (100%)	21 290 940 kWh (91.33%)
Unitary consumption (excluding garages)	278.0 kWh/m²/year	253.9 kWh/m²/year
Annual cost	$650 581.32	$710 883.30
Unitary cost (excluding garages)	$7.76/m²/year	$8.48/m²/year

THE TABLE 2.4 SHOWS THE MAIN CONSUMPTION FACTORS IN THIS ENERGY BALANCE. WE CAN SEE THAT THE MAIN CONSUMPTION LOADS WERE, BY ORDER, THE LIGHTING WHICH USES NEARLY 30% OF THE TOTAL ENERGY CONSUMPTION, THE HEAT PUMP MOTORS ROUGHLY 25% OF THE CONSUMPTION, THE VARIOUS FAN AND PUMP MOTORS FOR 17% AND THE COMPUTERS FOR 13%.

AIR CONDITIONING CHILLERS CONSUME ONLY 6% OF THE TOTAL ENERGY WHILE THE REMAINING LOADS ARE MARGINAL. NET HEATING NEEDS ARE EVALUATED TO LESS THAN 1% OF THE ENERGY BALANCE. AS MENTIONED BEFORE, THIS ENERGY BALANCE HAS BEEN COMPUTED AS PER THE CALCULATION OF HEATING AND AIR-CONDITIONING LOADS.

TABLE 2.4 - ENERGY BALANCE

	ANNUAL CONSUMPTION	%	DEMAND kW	
			WINTER	SUMMER
LIGHTING	6,267,000	29.3	1,600	1,600
COMPUTER	2,851,400	13.3	555	555
MOTORS	3,678,000	17.2	715	785
HEAT PUMPS	5,516,000	25.8	1,110	885
WATER CHILLERS	1,277,700	6.0	375	585
HOT WATER	65,600	--	Off peak	-
ELECTRICAL HEATING	165,000	--	50	-
KITCHEN	325,000	1.5	250	250
ELEVATORS & ESCALATOR	918,000	4.3	210	210
MISCELLANEOUS SERVICES	330,000	--	50	50
	21,387,800		4,915	4,920

PART III

THE OVERALL INTENT OF THIS STUDY WAS TO IDENTIFY AND HIGHLIGHT THE FACTORS THAT PERMIT THE REVENUE BUILDING TO OPERATE AT A VERY LOW ENERGY CONSUMPTION FACTOR, CURRENTLY IN THE MAGNITUDE OF 250 kWh PER SQUARE METER PER YEAR. OUR STUDY PERMITTED TO IDENTIFY ELEVEN FACTORS WHOSE GLOBAL IMPACT ON THE ENERGY CONSUMPTION CAN BE EVALUATED AT 190 kWh PER SQUARE METER PER YEAR. WITHOUT THESE FACTORS, THE UNITARY CONSUMPTION OF THE BUILDING WOULD LIKELY BE IN THE MAGNITUDE OF 440 kWh PER SQUARE METER PER YEAR, A FIGURE IN THE ORDER OF THOSE OF EXISTING SIMILAR OFFICE BUILDINGS.

THESE FACTORS WERE REGROUPED UNDER TWO MAIN CATAGORIES, FIRST, THE "INHERENT UTILIZATION FACTOR" DERIVING FROM THE NATURE OF THE BUILDING OR THE UTILIZATION THE USERS EXPECT FROM THE BUILDING.

SECOND, THE ESSENTIAL ENERGY EFFICIENCY FACTORS DERIVING FROM SPECIFIC AND INTENTIONAL ENERGY SAVING FEATURES OR DESIGN CHOICES.

WE ALSO SUGGESTED SOME POTENTIAL ADDITIONAL ENERGY SAVINGS THAT COULD EASILY BE REALIZED.

THE TABLE 3.1 SUMMARIZES THESE FACTORS AND THEIR IMPACT ON ENERGY CONSUMPTION.

TABLE 3.1 - SUMMARY OF RESULTS

FACTORS	IMPACT ON ENERGY CONSUMPTION		
	ANNUAL CONSUMPTION MWH/YEAR		UNITARY CONSUMPTION kWh/m²/YEAR
I- UTILIZATION FACTORS		%	
1. Envelope/floor area	2895	18.1	34.5
2. Reduced occupancy density	388	2.4	4.6
SUB-TOTAL	3283		39.1
II- ENERGY EFFICIENCY FACTORS			
3. Reflecting glass	130	--	1.6
4. Roof & wall insulation	220	1.4	2.6
5. Lighting Reduction Program	2732	17.1	32.6
6. Garage heating & ventilation	3006	18.7	35.9
7. a. Minimum fresh air rate	1209	7.6	14.4
b. Recirculation during non-occupied periods	1808	11.3	21.6
8. Garage ceiling space heating	337	2.1	4.0
9. Heat recovery from heat pumps	2925	18.3	34.9
10. Heat recovery from exhaust air	313	2.0	3.7
11. Lower temperature of domestic hot water	50	--	0.6
SUB-TOTAL	12730		151.9
TOTAL I & II	15993	100.0	191.0
III- POTENTIAL ADDITIONAL ENERGY SAVING MEASURES			
12. a. Further lighting reduction	672		8.0
b. Optimized lighting control	313		3.7
13. Stoppage of secondary air systems	112		13.4
SUB-TOTAL	1097		25.1

THE FIRST FACTOR "ENVELOPE TO FLOOR AREA" RATIO RELATES TO THE BUILDING ARCHITECTURAL APPROACH, THE "BULKY LOW PROFILE" SHAPE OF THE BUILDING. WE WILL COME BACK TO THIS FACTOR LATER.

THE SECOND FACTOR, THE "REDUCED OCCUPATION DENSITY" TAKES INTO ACCOUNT THE FACT THAT 2800 PEOPLE AT THE REVENUE BUILDING OCCUPY AN AVERAGE AREA OF 30 SQUARE METERS PER PERSON VERSUS AN AVERAGE OF 14 TO 16 SQUARE METERS PER PERSON IN OTHER OFFICE BUILDINGS. THE IMPACT OF THIS REDUCED POPULATION ON AIR-CONDITIONING, HOT WATER CONSUMPTION AND OTHER ENERGY USE, ALTHOUGH SMALL, IS NOT NEGLIGIBLE.

THE THIRD FACTOR "UTILIZATION OF REFLECTING GLASS", INSTEAD OF ORDINARY CLEAR DOUBLE GLASS, HAS A SMALL EFFECT ON THE AIR-CONDITIONING ENERGY CONSUMPTION. IN THE CASE OF THE REVENUE BUILDING, WE NOTICE THAT THE RECYCLING OF HEAT GAINS DURING THE HEATING SEASON DIMINISHES THE ADVANTAGE OF A REFLECTIVE GLASS.

THE FOURTH FACTOR "ROOF AND WALL INSULATION" EVALUATES THE IMPACT OF 76 MM OF RIGID INSULATION VERSUS 51 MM OF RIGID INSULATION IN SIMILAR BUILDINGS.

THE FIFTH FACTOR IS RELATED TO THE "LIGHTING INTENSITY" AND WE WILL COME BACK TO THIS LATER.

THE SIXTH FACTOR "GARAGE HEATING AND VENTILATION" IS A MAJOR CAUSE OF ENERGY EFFICIENCY IN THIS BUILDING, AND AGAIN, WE WILL REVIEW IT IN MORE DETAIL LATER.

FACTORS SEVEN "A" AND "B" ARE RELATED TO THE VENTILATION RATE OF THE BUILDING. FIRST "A", THE TOTAL FRESH AIR FLOW OF THE BUILDING, AND "B" THE FACT THAT NO FRESH AIR IS INJECTED IN THE BUILDING DURING THE UNOCCUPIED PERIODS.

FACTOR EIGHT, "GARAGE CEILING SPACE HEATING". ORIGINALLY, THE SUB-FLOOR OF THE FIRST OCCUPIED STOREY WAS HEATED WITH NINETY-FIVE 1.5 kW ELECTRIC ELEMENTS TO ACCOUNT FOR THE LOSSES TO THE UNHEATED GARAGE.

AS SOON AS 1980, THE MAINTENANCE PERSONNEL DISCONNECTED THESE ELECTRIC ELEMENTS, AND CIRCULATED THE MECHANICAL ROOM EXHAUST AIR ACROSS THE SPACE FOR HEATING PURPOSES. THE IMPACT ON ENERGY REDUCTION IS AGAIN SMALL, BUT NOT NEGLIGIBLE.

THE FACTOR NINE IDENTIFIES A SAVING RELATED TO THE "ENERGY RECYCLED BY THE PERIMETER HEAT PUMPS".

FACTOR TEN "HEAT RECOVERY FROM EXHAUST AIR" EVALUATES THE SAVING OF THE ENERGY RECOVERY HEAT EXCHANGER BETWEEN THE EXHAUST AND THE FRESH AIR INTAKE.

FINALLY, DOMESTIC HOT WATER IS MAINTAINED AT $35^{o}C$ INSTEAD OF $60^{o}C$.

FURTHER ENERGY SAVINGS COULD BE OBTAINED BY FIRST REPLACING 40-WATT FLUORESCENT TUBES WITH 35-WATT TUBES. A PROGRAM OF REPLACEMENT IS ALREADY IN PROGRESS AND WOULD PRODUCE A TOTAL REDUCTION OF ABOUT 200 kW.

SECOND, WE ESTIMATE THAT A TIGHTLY CONTROLLED LIGHTING SCHEDULE TAKING INTO ACCOUNT SPECIAL ACTIVITIES AND HOUSECLEANING COULD ALLOW FOR A FURTHER REDUCTION OF 5% IN THE LIGHTING EXPENSES.

FINALLY, THE SECONDARY AIR SYSTEMS ARE PRESENTLY WORKING AT LOW VELOCITY DURING THE UNOCCUPIED HOURS. THESE SYSTEMS COULD BE STOPPED PROVIDING FOR ADDITIONAL SAVINGS.

NOW, LET'S COME BACK TO SOME IMPORTANT FACTORS THAT WE PREVIOUSLY MENTIONED. FIRST, THE ENVELOPE TO FLOOR AREA RATIO. FOR ANALYSIS PURPOSES, WE COMPUTED THE GROSS FLOOR AREA TO EXPOSED WALL AREA RATIO OF THE REVENUE BUILDING AND COMPARED IT TO SIMILAR BUILDINGS IN THE MONTREAL REGION. THIS FACTOR, MAINLY THE RATIO OF ENVELOPE TO THE USABLE FLOOR AREA, VARIES FROM 1.8 TO 2.8 FOR AN AVERAGE OF 2.16 FOR SIMILAR BUILDINGS IN MONTREAL, BUT IS AT 4.20 AT THE REVENUE BUILDING. IF WE EXCLUDE THE GARAGE, THE AVERAGE IS 1.86 BUT THE REVENUE FIGURE IS 2.73.

TABLE 3.2 - RATIO OF ENVELOPE TO USABLE FLOOR AREA

BUILDING	TOTAL FLOOR AREA / EXPOSED WALL	RATIO: FLOOR / EXPOSED WALL	FLOOR AREA LESS GARAGES / EXPOSED WALL	RATIO: FLOOR / EXPOSED WALL
Ste-Justine Hospital	112 570 m² / 47 425 m²	2.37	11 200 m² / 47 425 m²	2.36
Hydro-Quebec Headquarters	30 590 m² / 15 616 m²	1.96	22 350 m² / 15 610 m²	1.43
Place Victoria	121 890 m² / 43 490 m²	2.80	110 000 m² / 43 490 m²	2.53
Attorney General Building	69 950 m² / 39 020 m²	1.79	61 490 m² / 39 020 m²	1.58
RCMP Building	26 270 m² / 13 930 m²	1.84	19 626 m² / 13 930 m²	1.40
Average:		2.16		1.86
REVENUE BUILDING	129 500 m² / 30 720 m²	4.21	83 847 m² / 30 720 m²	2.73

THIS MEANS THAT FOR THE SAME ENVELOPE AREA OR THE SAME EXPOSED WALLS AND WINDOWS, THE REVENUE BUILDING HOUSES NEARLY TWICE AS MUCH SQUARE METERS OF USABLE FLOOR SPACE. THE IMPACT OF THE REDUCED EXPOSED ENVELOPE IS FELT ON HEATING LOADS AND THE EXPENSE ASSOCIATED WITH LOSSES. TAKING BACK THE RATIO OF AN AVERAGE BUILDING AND APPLYING IT TO THE REVENUE BUILDING, WE COMPUTED THE SUPPLEMENTARY EXPOSED AREA IN THE WALLS AND WINDOWS, ASSUMING A 46% FENESTRATION COEFFICIENT, AND COMPUTED SUPPLEMENTARY HEAT LOSSES OF THESE SURFACES.

THE LAST REMARK ABOUT THE ENVELOPE TO FLOOR AREA RATIO WOULD BE REGARDING THE EFFICIENCY OF HEAT RECOVERY. BECAUSE OF THEIR RELATIVE HIGH HEAT LOSSES, HIGH ENVELOPE TO FLOOR RATIO BUILDINGS, HIGH, SLENDER AND THIN BUILDINGS, FOR EXAMPLE, WOULD SHOW LESS FACILITY TO MATCH HEAT LOSS LOADS TO INTERNAL GAINS, THUS PENALIZING THE OVERALL EFFICIENCY OF THE HEAT RECOVERY SYSTEMS. IN BULKY BUILDINGS, LIKE THE REVENUE BUILDING, HIGH INTERNAL GAINS ARE MET WITH RELATIVELY LOWER HEATING LOADS, THUS INCREASING THE EFFECTIVENESS OF THE HEAT RECOVERY SYSTEM.

THE LIGHTING REDUCTION PROGRAM:

THE ORIGINAL LIGHTING LOAD WAS 2460 kW.

AS EARLY AS THE FALL OF 1980, THE MAINTENANCE PEOPLE OF THE BUILDING STARTED TO DISCONNECT PERMANENTLY, A CERTAIN NUMBER OF FIXTURES. AT THE BEGINNING OF 1983, THE TOTAL LIGHTING LOAD HAS BEEN REDUCED TO 1600 kW. THE REDUCTION OF THE ELECTRIC PEAK IS THEN OF 860 kW AND THE SAVING ON THE ANNUAL CONSUMPTION BASED ON THE LIGHTING SCHEDULE MENTIONED BEFORE IS CONSIDERABLE.

THE GARAGE HEATING AND VENTILATION. AT THE REVENUE BUILDING, THE CHARACTERISTICS OF THE GARAGE VENTILATION SYSTEMS ARE:

- THE VENTILATION IS CONTROLLED (STOP AND START) BY CARBON-MONOXYDE DETECTORS;

- TOTAL AIR FLOW IS 236,000 LITRES PER SECOND;

- NEITHER THE GARAGE NOR THE VENTILATION AIR ARE HEATED.

COMPARED TO STANDARD PRACTICE WHERE:

- VENTILATION IS ON CONTINUOUS BASIS DURING THE WORKING DAYS, 10 HOURS PER DAY;

- FRESH AIR IS ADMITTED ON DEMAND BY A DETECTOR;

- PREMISES AND VENTILATION AIR ARE HEATED TO $10^{o}C$

AGAIN THE SAVINGS REALIZED AT THE REVENUE BUILDING ARE VERY IMPORTANT. IN OUR ANALYSIS, THIS FACTOR IS ONE, IF NOT THE MOST, IMPORTANT FACTOR IN ENERGY EFFICIENCY.

VENTILATION RATE:

ACCORDING TO STANDARD PRACTICE, THE MINIMUM FRESH AIR RATE INTRODUCED IN OFFICE BUILDINGS IS AROUND HALF A LITRE PER SECOND PER SQUARE METER. TAKING INTO ACCOUNT THE POSSIBILITY OF EXHAUST RECIRCULATION WHEN THE OUTDOOR TEMPERATURE IS BELOW $-18^{o}C$, THE MINIMUM ACTUAL FRESH AIR FLOW INTRODUCED INTO THE REVENUE BUILDING IS 28 000 LITRES PER SECOND OR APPROXIMATELY 0.34 LITRE PER SECOND PER SQUARE METER. ON THE WHOLE, THE DIFFERENCE IN FRESH AIR FLOW REPRESENTS 13 400 LITRES PER SECOND AND AGAIN, THE SAVINGS ASSOCIATED WITH HEATING, HUMIDIFYING AND AIR-CONDITIONING ARE VERY SUBSTANTIAL.

MOREOVER, THE PRIMARY FANS, THE ONES THAT SUPPLY FRESH AIR INTO EACH FLOOR, ARE STOPPED EVERY DAY, ABOUT 14 HOURS PER DAY, AND THE LOCAL DECENTRALIZED VENTILATION SYSTEM THEN OPERATES ON 100% RECIRCULATION. THE SAVINGS ARE AGAIN REALIZED BY NOT HEATING, HUMIDIFYING AND AIR-CONDITIONING FRESH AIR DURING THAT PERIOD.

HEAT RECOVERY FROM HEAT PUMPS NETWORK: THE SURVEY MADE WITH THE MAINTENANCE PERSONNEL SHOWED THAT THE MINIMUM WINTER AIR-CONDITIONING LOAD IS ABOUT 1250 kW DURING THE DAY, 10 HOURS PER DAY. OUR OWN ANALYSIS EVALUATES THIS LOAD AT 1215 kW. ON THE OTHER HAND, THE REJECTION TO THE COOLING TOWERS IS NECESSARY ONLY WHEN THE COOLING LOAD REACHES 1400 TO 1500 kW, WHEN THE OUTDOOR TEMPERATURE IS ABOUT -10°C. UP TO THIS POINT, EXCESS HEAT IS SENT TO THE THERMAL RESERVE. IT IS CONSERVATIVELY ESTIMATED THAT THE CAPACITY OF HEAT RECOVERY IS ABOUT 1500 kW, 10 HOURS PER DAY, DURING A MINIMUM PERIOD OF 5 MONTHS.

KNOWING THAT SOME RECOVERY OCCURS YEAR-ROUND, SUCH AS DOMESTIC HOT WATER PRE-HEATING, OVER THIS PERIOD, THE MINIMUM AMOUNT OF ENERGY RECOVERED TO THE HEAT PUMP IS ESTIMATED AT 2 925 000 kWH PER YEAR, EQUIVALENT TO 34.9 kWH PER SQUARE METER PER YEAR. THIS QUANTITY OF ENERGY NEARLY EQUALS THE ACTUAL HEATING NEEDS, LEAVING A REMAINDER OF 165 000 kWH PER YEAR OF

NET HEATING NEEDS THAT ARE SUPPLIED BY THE ELECTRIC BOILERS OPERATING DURING OFF-PEAK PERIODS.

FINALLY, WE CAN CONCLUDE THAT THE LOW ENERGY USE FACTOR AT THE REVENUE BUILDING CAN BE ATTRIBUTED TO FIVE MAIN FACTORS:

- FIRST, THE BUILDING ARCHITECTURAL APPROACH OF A LOW PROFILE BULKY BUILDING THAT HAS RELATIVELY FEW EXPOSED WALLS;

- SECOND, A HEAT PUMP RECOVERY SYSTEM THAT ALLOWS THE RECYCLING OF INTERNAL GAINS TO HEATING LOSSES;

- THIRD, A LOW DENSITY LIGHTING SYSTEM;

- FOURTH, A MINIMUM FRESH AIR RATE REDUCED TO ZERO DURING UNOCCUPIED PERIODS;

- FIFTH, NO HEATING OF THE GARAGE AND ITS VENTILATION AIR.

THESE FACTORS ACCOUNT FOR 90% OF THE EFFICIENCY OF THE BUILDING.

PART IV

IN THE LAST PART OF THIS EXPOSÉ, WE WILL HAVE A FINAL LOOK AT THE CONCEPT OF PERIMETER ZONE HEATING AND AIR-CONDITIONING BY MEANS OF INDIVIDUAL HEAT PUMPS. DECENTRALIZED HEAT PUMPS ARE CONSIDERED BY MANY, AS A PREFERRED SYSTEM FOR PUMPING HEAT FROM THE COOL AREAS TO THE HEATING ZONES. HOWEVER, THIS SYSTEM PRESENTS A MAJOR DISADVANTAGE IN REGARD TO ITS EFFICIENCY.

TO UNDERSTAND THIS MAIN DISADVANTAGE FROM AN ENERGY EFFICIENCY STANDPOINT, THIS CONCEPT HAS TO BE COMPARED, FOR ENERGY PUMPING PURPOSES, TO THE CENTRAL CENTRIFUGAL COMPRESSOR OPERATING IN A RECUPERATIVE WAY.

ENERGY PUMPING COMPARISON

PERFORMANCE COEFFICIENTS

	Centrifugal chiller	Decentralized heat pump
Chilling cycle	5.2	2.8
Heating cycle	6.1	3.6

ENERGY TO SUPPLY 1 kW OF HEATING

		kW		kW
Compressor	1/6.1	0.16	1/3.6	0.28
			0.72/2.8	0.26
Water circulating power		0.15		0.10
TOTAL		0.31		0.64
Global COP		3.2		1.6

FIRST, IF WE HAVE A LOOK AT THE OPERATING EFFICIENCY COP (COEFFICIENT OF PERFORMANCE) OF THE CENTRIFUGAL CHILLER AND THE INDIVIDUAL HEAT PUMP, WE CAN SEE THAT THE CENTRIFUGAL CHILLER CAN OPERATE IN THE CHILLING CYCLE WITH A COP OF 5.2 AND IN THE HEATING CYCLE, WITH A COP OF 6.1. EACH INDIVIDUAL HEAT PUMP OPERATES FOR THE SAME CYCLES AT A CONSIDERABLY LOWER COP; RESPECTIVELY 2.8 AND 3.6. FOR THE OVERALL CYCLE, THE CENTRIFUGAL CHILLER USES 1 kW OF MOTOR POWER AND REJECTS 6.1 kW TO THE HEATING ZONE, WHILE THE DECENTRALIZED HEAT PUMP INVOLVES 2 MOTORS, SAY 2 kW TO REJECT 3.6 kW. TWO DECENTRALIZED HEAT PUMPS ARE INVOLVED IN PUMPING ENERGY FROM THE COOLING ZONE TO THE HEATING ZONE.

TAKING INTO ACCOUNT THE WATER CIRCULATING POWER, THE CENTRAL SYSTEM USES,FOR EACH kW REJECTED TO THE HEATING ZONE, 0.15 kW OF WATER CIRCULATING POWER AND 0.16 kW FOR THE CHILLER. THE GLOBAL COP IS THEN 1 kW OVER 0.35 kW, OR 3.2. SIMILARLY THE DECENTRALIZED HEAT PUMP NETWORK USES FOR EACH kW OF REJECTION ENERGY 0.28 kW FROM THE HEATING HEAT PUMP, 0.26 kW FROM THE COOLING HEAT PUMP AND SAY 0.1 kW OF CIRCULATING POWER.

THE GLOBAL COP IS THEN 1 OVER 0.64 OR 1.6, HALF THE EFFICIENCY OF THE CENTRIFUGAL CHILLER.
THE MEAN COEFFICIENT OF PERFORMANCE OF THE COOLING SEASON WOULD BE EVEN INFERIOR TO THAT FIGURE IF WE CONSIDER THAT WE CAN NEVER ACHIEVE FREE COOLING TO AIR-CONDITION THE PERIMETER ZONE WITH THIS TYPE OF SYSTEM. IN THE CASE OF THE REVENUE BUILDING, HEAT PUMPING REALIZED BY A CENTRAL CHILLER WOULD HAVE INVOLVED, AROUND HALF OF THE HEAT PUMPS CONSUMPTION, 2 800 000 KWH OR 22 KWH PER SQUARE METER PER YEAR LESS, OR A SAVING OF 13% IN REGARD TO THE PRESENT LEVEL.

IN CONCLUSION, THE DOUBLE PUMPING THAT TAKES PLACE, AND THE FACT THAT WE CANNOT ACHIEVE ANY FREE COOLING DURING THE WARM SEASON CONSTITUTES INHERENT WEAKNESSES TO THE DECENTRALIZED HEAT PUMP SYSTEM, AS FAR AS ENERGY CONSERVATION IS CONCERNED. FURTHERMORE, THIS SYSTEM REQUIRES A HIGH ELECTRICAL DEMAND IN WINTER, FIRST TO

EXECUTE THE HEAT REJECTION DURING THE HEATING SEASON, THEN TO AIR-CONDITION IN MID-SEASONS AND HIGH ANNUAL ENERGY COSTS.

NOW, LET'S HAVE A LOOK AT THE WATER CIRCULATING ENERGY INVOLVED IN THIS SYSTEM. BECAUSE OF THE INHERENT CHARACTERISTICS OF THIS SYSTEM, FULL FLOW PUMPING IS REQUIRED ON A CONTINUOUS BASIS. WATER CIRCULATING ENERGY FOR THE HEAT PUMP NETWORK IS EVALUATED AT THE REVENUE BUILDING AT 1,600,000 kWh PER YEAR OF 7.4% OF THE TOTAL BUILDING CONSUMPTION.

STOPPING THE PUMPS, WHENEVER POSSIBLE, DURING NON-OCCUPANCY PERIODS DURING SUMMERTIME, OR DURING THE TEMPERATURE SET BACK PERIOD, SHOULD HAVE A SIGNIFICANT IMPACT ON THIS EXPENSE. FURTHERMORE, ANYONE ENVISIONING THE DESIGN OF A DECENTRALIZED HEAT PUMP SYSTEM SHOULD CONSIDER TWO-WAY VALVES TO MINIMIZE THE WATER CIRCULATION ENERGY CONSUMPTION. WE SHOULD ALSO NOTICE THE OPEN-TYPE THERMAL RESERVE THAT ADDS TO THE PUMPING EXPENSE.

FINALLY, WE SHOULD CONSIDER THE PRIMARY AIR SYSTEM. USE OF A SEPARATE SYSTEM FOR MAKE-UP AIR TREATMENT PERMITS EASY CONTROL OF THE EXPENSE ASSOCIATED WITH FRESH AIR, ESPECIALLY BY ITS EASE OF SCHEDULING.

WE CONSIDER THAT THESE BENEFITS SHOULD EXTEND TO THE USE OF THAT MINIMAL MAKE-UP AIR FLOW FOR "FREE-COOLING" PURPOSES. IN THE CASE OF THE REVENUE BUILDING, MAKE-UP AIR IS CENTRALLY HEATED AND HUMIDIFIED, WHILE LOCAL SYSTEMS COOL AND DEHUMIDIFY MIXED AIR, IF REQUIRED. WE ACKNOWLEDGE THAT PROPER CONTROL STRATEGIES PROBABLY PREVENT THE DOUBLE EXPENSE ON MAKE-UP AIR. NEVERTHELESS, CONSIDERING THE HEATING SEASON, THE "FREE-COOLING" EFFECT OF MAKE-UP AIR SHOULD BE PRECISELY COMPUTED, ESPECIALLY IN THE CASE OF A LARGE CORE AREA BUILDING LIKE THE REVENUE BUILDING.

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE E.I WOOD BUILDING
SWIFT CURRENT, SASK.

by

Jeff Osborne, P.Eng.
Yoneda and Associates, Ltd.
Regina, Sask.

OBJECTIVES

It has frequently been difficult to establish norms for energy consumption in buildings, because of differing occupancies, climatic variations, lack of recorded data, systems and operation, but the escalation in energy costs over recent years has prompted a serious interest in these subject areas.

The focus of the study is primarily exploratory, with direction obtained through a review of available energy consumption data, mechanical engineering theory, and relevant experience. This study helps to eliminate from future research these variables that do not have a significant effect on the overall level of energy consumption. In addition, it provides some insight into the relationship between the level of energy consumption and basic design/operating parameters incorporated into subject buildings. Further work on these relationships should eventually make available to building designers detailed information regarding successful energy efficient buildings and systems.

VERIFICATION OF THE E.S.A. MODEL

The first phase of this study was to establish accuracy of the Meriwether E.S.A. computer simulation, as compared to actual monthly and yearly detailed energy consumption records. In doing so, detailed operating records, proce ures, and costs were obtained for the test building. Operation for one year was then simulated and resultant electrical and natural gas consumption levels were compared with utility records for both monthly and yearly values.

It was determined that the computer simulation yielded comparable results for both seasonal trends and yearly consumption figures, thus deeming the simulation acceptable. Simulated gas consumption was 7.0 percent lower than the actual gas value with simulated electrical consumption 0.9 percent higher than actual values. Actual energy consumption for calendar year 1981 was 1047.6 $MJ/m^2.yr$ (27.0 $kWhr/ft^2.yr$) with a computer simulated value of 1018.8 $MJ/m^2.yr$ (26.3 $kWhr/ft^2.yr$).

The next phase in the modelling process was to simulate building operation with no energy conservation techniques in place, serving as a base or standard against which various energy conservation parameters would be compared.

The base model achieved an overall energy consumption level of 1505.7 $MJ/m^2.yr$ (38.9 $kWhr/ft^2.yr$). From this base, various energy saving modes of operating strategies were investigated and compared. It should be noted that the base model energy consumption (e.g. no energy conservation strategies in place) was 44 percent higher than the actual energy consumption for calendar year 1981.

BUILDING DESCRIPTION

To coincide with the study scope, a building possessing low annual energy consumption characteristics was utilized, and the E.I. Wood Building, located in Swift Current, Saskatchewan, was selected. Owned and operated by the Government of Saskatchewan, Department of Government Services, the overall energy consumption and all retrofitting have been documented since original occupancy.

Constructed in the summer of 1977, the five storey rectangular office building has a total area of 10680 square meters of which 8270 square meters is occupied office space. Main floor dimensions are 60.8 meters by 26.8 meters with an increase of 0.6 meters in both dimensions for each ascending floor. A central stairwell is located on the south interior with glass enclosed fire escape towers on either end of the building. Wall construction comprises a precast concrete outer shell with rigid insulation, air space, and drywall to complete the inner wall envelope. Roof construction is also precast concrete with rigid insulation and gravel ballast, yielding composite R values of 3.0 $m^2.{}^oC/W$ and 4.6 $m^2.{}^oC/W$ respectively for walls and roof. Grey reflective double pane fenestration units represent approximately 30 percent of the exterior surface area on all exposures, with partial window shading attributed to concrete overhangs.

Internally, the building is separated into two wings, each divided by a central corridor. The office area ceiling, a concrete slab sprayed with cellulose fibre, is exposed, with both lighting and ductwork suspended below. Unlike the office ceiling, the central corridor is a lower metal ceiling, concealing all ductwork and lighting. Fluorescent fixtures provide an installed lighting level of 130 kJ/hr.m^2, although subsequent delamping has reduced this value to 71 kJ/hr.m^2

The all air system is a variable air volume configuration supplying a total air volume of 52,370 L/s or 4.9 L/s.m^2. The thermostatically controlled variable air volume terminals modulate from 100 percent air flow down to 40 percent. Perimeter supply air grilles are located in the floor while interior air is supplied from the ceiling. The central corridor ceiling space serves as a return air plenum connecting to a common vertical shaft behind the elevator rising into the penthouse. An economizer cycle modulates outside air volume from 100 percent of total supply air volume during the free cooling periods of fall, winter, and spring, down to a minimum 15 percent. Four exhaust fans service the kitchen, washrooms, elevator room, and conference room areas, exhausting a total capacity of 2990 L/s.

The mechanical penthouse, located on the roof, contains two

natural gas 75 kW, 118.7 kcal/m^3.hr input, Minifin boilers providing hot water heating via a convertor, and steam humidification. Chilled water is supplied from a 275 ton, 224 kw input, Trane Centravac chiller with a B.A.C. ejector cooling tower.

Air handling is provided by 8 octagonal centrifugal fans, four dedicated to supply air service, and four to return air service. Pneumatically controlled scroll bypass dampers and inlet vanes modulate during fan operation to provide the required supply air flow called for by the VAV terminals. Primary cooling coils are located in the fan room with heating coils located in the variable air volume terminals. The mechanical system features night set-back/set-up temperatures, fan cycling to hold set-back/set-up temperatures, deadband thermostats, night shut-off of all exhaust systems, and an economizer cycle.

BUILDING OPERATIONS

Since original occupancy in 1977, the Saskatchewan Government has frequently altered operational procedures of the E.I. Wood Building, striving for more efficient energy utilization. By adopting the various energy conservation techniques discussed in the following sections, these ongoing energy programs have substantially reduced the 1978 annual consumption figure of 1937 $MJ/m^2.yr$ (50 $kWhr/ft^2.yr$) to a 1981 value of 1047.6 $MJ/m^2.yr$ (27.0 $kWhr/ft^2.yr$).

Basically, the building is currently operated on a series of time clocks with associated schedules. Approximately 300 people occupy the building from 7:00 a.m. to 7:00 p.m., Monday to Friday, with most occupants present from 8:00 a.m. to 5:00 p.m.

The air handling system is scheduled to perform in the following manner; for cooling operation, the deadband thermostats are set at 24°C for occupied hours and 37°C for unoccupied hours. For heating operation, the deadband thermostats are set at 21°C for occupied hours and 18°C for unoccupied hours. Current operation has the setback to 14°C (such extensive setback is not recommended and will be discussed later). The fans cycle to maintain these unoccupied thermostat settings from 8:00 p.m. to 6:00 a.m.

All systems, with the exception of boilers, are run on time clocks designed to cycle the various systems off during unoccupied hours. At present, outside air intake dampers are closed during unoccupied hours, but were constantly on minimum 15 percent outside air during the 1981 simulation year.

Extensive delamping throughout the building has reduced the installed lighting capacity value of 130 kJ/hr.m^2 in 1977. Significantly altered areas include corridors, washrooms, and exterior offices, with stairwells being reduced to 10 percent of the original 10.6 kw value. During the 1981 simulation, lighting capacity was approximately 79 percent of the original installed level of 385.3 kw; a lighting level of 103 kJ/hr.m^2.

The second floor cafeteria operates from 8:00 a.m. to 4:30 p.m., offering hot meals at lunch for approximately 100 people. Kitchen exhaust is on at 7:00 a.m., shutting off at 4:30 p.m., with continuous operation during the day.

Cleaning staff work in the afternoon, thus negating the necessity for lights and air systems to operate at nights.

RECOMMENDATIONS

The following is an analysis of the results and expected savings by utilizing energy saving techniques.

NIGHT RESET WITH DEADBAND THERMOSTATS

As expected, simulation of building operation, with the above described strategies incorporated, resulted in natural gas and electrical consumptions significantly lower than the base test model. Gas consumption decreased 14.1 percent with the steam demand peak down 11.5 percent. Electrical consumption was reduced 11.3 percent with a peak demand increase of 1.9 percent. The slight increase in electrical peak demand is due to increased pick-up load encountered when space conditions switch back to an occupied set-point. Overall consumption was reduced from the base 1505.7 $MJ/m^2.yr$ (38.9 $kWhr/ft^2.yr$) to 1320.7 $MJ/m^2.yr$ (34.1 $kWhr/ft^2.yr$), a 12.3 percent reduction in overall energy requirements.

It should be noted that a simulation with deadband thermostats installed versus the base model was also investigated. Electrical consumption was reduced 1.0 percent with a corresponding peak demand increase of 1.0 percent. Natural gas consumption reduced 3.2 percent with a 1.9 percent steam demand reduction. Overall energy consumption decreased 1.7 percent to

1479.0 MJ/m^2.yr (38.2 kWhr/ft^2.yr).

Caution is advised in selecting both the set-back temperature and fan cycling hours, as the law of diminishing returns plays a key role. If the set-back temperature difference is greater than 3°C to 4°C, the mechanical system must overcome a substantial pick-up load when returning to the occupied space heating mode at the beginning of each day. This problem is especially relevant when the set-back mode spans a weekend. During such extended periods, building thermal mass or "flywheel effect" has had significant time to reduce in temperature and thus when returning to an occupied mode, the building temperature will not immediately be maintained but rather, could take as much as one day to recover. This pick-up load becomes critical when the heating system is electric, because as capacity is exceeded when returning to the occupied mode, electrical demand charges escalate.

Various simulations were performed modelling the E.I. Wood building utilizing electric heat with 0°, 4°, and 6°C set-back temperatures. Although the 6°C set-back simulation reduced total operating costs by 3.3 percent, this figure deems further investigation. Saskatchewan possesses one of the lowest energy rates in Canada, that being $6.65 per kV-A of demand and 3.04¢ per kWh. As demand in the simulation increased by 4.4 percent, the operating costs in another area of Canada may very well

increase, depending on demand and consumption rates.

Also, other factors besides the energy reduction should be considered. Human comfort plays an important role in set-back and although additional set-back may yield additional savings, the inadequacy of the heating system to meet space requirements when returning to an occupied mode is of serious consequence. In the set-back simulations, an additional two hours of pick-up load was encountered in the 6°C set-back modes as opposed to the 0°C set-back mode.

Finally, set-back is related to building structure in terms of the percentage of interior to exterior area, occupied operating hours, thermal mass, etc., and thus the exact set-back temperature can vary significantly for each particular building.

With regard to summer operation, high pick-up loads will be encountered if the air system is shut-off prematurely. Space peak cooling loads are encountered between 4:00 p.m. to 6:00 p.m. with latent loads experienced even later. By not affording the building time to cool down, the air system again has a pick-up load far exceeding its capacity, ultimately increasing the electrical peak demand requirement. Again, the conservation of electrical demand is a critical feature of building operation.

It is therefore recommended that the fan system run one to two hours in the morning, especially during summer periods when ambient temperature is not cool enough to naturally reduce the building heat load and mechanical cooling is required. In doing so, the mechanical system has an opportunity to gradually reduce the high space temperatures, and thus alleviate the associated significant pick-up load. In addition, heavy pick-up loads may be reduced by "staging", that is, the process of returning the temperature setting to an occupied mode in incremental steps.

Because of the nominal capital expense, an estimated pay-back for such an installation would likely be less than one year. A more significant parameter is the estimated savings encountered over a one year period. Ignoring inflation and escalation in energy rates, estimated savings of $5,493.00 are attained.

The installation of timers, which cycle fan systems and set-back thermostats is highly recommended, not only for its obvious energy saving, but also because of nominal capital expense.

ECONOMIZER CYCLE

As expected, simulation with an economizer cycle resulted in a reduction in electrical chiller consumption of 10.8 percent, with a corresponding peak demand reduction of 1.5 percent. Overall natural gas consumption increased by 0.6 percent with a 3.8

percent peak demand decrease. Overall consumption was down 103.7 $MJ/m^2.yr$ (2.7 $kWhr/ft^2.yr$) to 1402.0 $MJ/m^2.yr$ (36.2 $kWhr/ft^2.yr$), a reduction of 6.9 percent.

The 1.5 percent annual electrical demand reduction figure is misleading. During summer months, the economizer cycle is relatively idle as the ambient temperature is generally greater than return air temperature. Thus, chiller operation is constant without the aid of the economizer. In the fall, winter, and spring months, when ambient temperature is below return air temperature, the economizer cycle is of great value. During these months, electrical peak demand is decreased a significant 10 percent, as the chiller electrical consumption is replaced by "free cooling" of outside air.

As reported, the natural gas consumption has slightly increased when utilizing the economizer cycle. This increase represents reheat energy expended in warming the conditioned air required to satisfy specific room conditions. The penalty of slightly increased gas consumption is resolved with the use of temperature sensors placed throughout the building, transmitting various space temperature conditions to the economizer controller. During the heating mode, the system would determine which space has the greatest heating load and adjusts the mixed air temperature to reduce the reheat load. In doing so, the system

will attempt to utilize reheat capacity to satisfy space conditions (and consequently reduced additional gas heating expense). A less significant contributing factor to the slightly increased gas consumption could be attributed to the additional humidity load encountered with the increased outside air quantities introduced.

There are two methods of controlling an economizer cycle; dry bulb control and enthalpy control.

Dry bulb controlled economizers compare ambient air temperature to return air temperature, modulating outside and return air dampers accordingly, based on the two temperatures, introducing full outside air when outside air temperature is lower than return air temperature.

Conversely, enthalpy controlled economizers compare the total heat content or enthalpy of both the return and ambient air, modulating dampers accordingly.

In a dry climate such as Saskatchewan, dry bulb controllers are often adequate although enthalpy control would be preferable for high humidity days. In regions typically experiencing high humidity levels, enthalpy controllers for economizers would be

recommended.

As the economizer is part of the existing system, estimated payback is not applicable. Estimated energy savings for a one year period are $12,869.00.

The application of an economizer cycle is highly recommended and used extensively in areas with low ambient air temperatures, especially when these occur concurrent with high solar loads. In Saskatchewan, these conditions are prevalent during the months of April, May, September, October and a portion of November.

DELAMPING

As expected, the electrical consumption values significantly decreased with corresponding increased gas consumption values. Electrical consumption was reduced 34.4 percent with a 32.7 percent reduction in peak electrical demand. Accordingly, gas consumption increased 12.2 percent with a 3.8 percent jump in peak demand. Overall consumption was reduced to 1232.4 $MJ/m^2.yr$ (31.8 $kWhr/ft^2.yr$) from the base 1505.7 $MJ/m^2.yr$ (38.92 $kWhr/ft^2.yr$), which represents a major saving of 18.12 percent in total energy utilization, for this operating strategy alone.

To fully realize the positive potential of delamping, the combined electrical reduction and gas increase deem further

investigation. Essentially, lighting is over 95 percent heat which represents a very significant heating medium. The 12.2 percent increase in gas consumption represents additional heating required to replace the heat previously radiated by the lights. Conversely, during periods of mechanical cooling, chiller electrical consumption is reduced as the delamping has reduced the building's net cooling load. Consequently, heating from lights is inefficient, as the cost of electricity is approximately four to five times the cost of natural gas, according to current Saskatchewan utility rates.

In 1982, the E.I. Wood Building underwent additional delamping and although the total consumption figure did not substantially reduce, relevant savings in operating costs were attained, as the higher electrical costs were replaced with lower gas costs. Estimated energy savings for a one year period are $44,346.00. Again pay-back would definitely occur within one year as the expense associated with delamping is minimal.

The practice of delamping or designing for lower lighting levels is highly recommended as total power consumption is reduced from both decreased cooling loads and decreased lighting levels.

ADDITIONAL ENERGY CONSERVATION TECHNIQUES

In addition to the aforementioned conservation techniques, the following is a list of additional operational modes which reduce energy consumption.

Night Shut-Off Schedules

Significant energy savings can be obtained by incorporating night shut-off schedules into system operation. Shutting off outside air and exhaust fans during unoccupied hours will reduce both heating and cooling loads.

By assuming that a) outside air requires heating until ambient conditions reach 9°C, b) a 75 percent efficient gas heating system, and c) 45 occupied hours per week, estimated heating energy costs are $1.20 per litre of outside air per year. By shutting off the outside air during unoccupied hours, an estimated savings of $0.88 per litre of outside air can be attained.

Demand Reset of Supply Air Temperatures

By definition, demand reset is the adjustment of supply air temperature either higher or lower as required to match the requirement of the temperature zone having the greatest demand. In a cooling mode, the supply air temperature would be set to match the needs of the space requiring the maximum amount of

cooling. The converse is true in a heating mode.

An estimate of expected energy savings when using demand reset of supply air temperature is very difficult to generalize as this value is very dependent upon building parameters and system design. Unlike a conventional conservation technique such as night shut-off, the installation of demand reset involves monitoring the building's operation to determine the response to heating/cooling loads versus various ambient air temperatures.

Domestic Hot Water Temperature Reduction

The average temperature setting for domestic hot water systems is approximately 60°C. Reducing this value to 38°C effectively reduces the gas input to the hot water heater. If additional heat is required for a specific application, localized inline booster heaters would be installed. This operating strategy reduces the heat losses from distribution piping, which may become significant in large buildings.

Humidification

Decreased heating costs can be expected with the reduction of relative humidity percentage, and the number of hours humidity is controlled. It is recommended that a humidity level of 15 percent is adequate for office areas during the winter season, and would be maintained during office hours only.

In two simulations, one maintaining 25% R.H. and the other maintaining 15% R.H., estimated humidification consumption was 4.45 MBTU/ft^2 and 1.62 MBTU/ft^2 respectively.

Fresh Air Reduction

Introducing fresh air to the air system during cold winter months requires a substantial amount of heat input. Reducing the outside air percentage will significantly reduce the corresponding heat input required. Care should be taken not to reduce this percentage below the minimum required by code to satisfy building occupants. Currently published recommendations of the Association of Heating, Refrigerating and Air Conditioning Engineers are generally accepted as the basis for design of outside air introduced into building systems.

Again assuming gas heating efficiency of 75 percent and required heating for ambient temperatures below 9°C, estimated energy costs are $1.20 per litre of outside air per year, assuming no

unoccupied hour shut-off.

It should be noted that certain conservation techniques, which may be applicable in other areas, do not necessarily pay-back in Saskatchewan. To cite two examples, consider the off-beat generation of chilled and/or hot water with storage of same, and the various applications of solar energy. Besides the substantial capital costs, Saskatchewan's present energy rate structure makes it difficult to justify such installations.

COMMENTS ON ACTUAL VS. SIMULATED ENERGY CONSUMPTION DATA

Although the energy consumption figures associated with simulated versus actual generally compare most favorably, definite discrepancies remain. The following comments are meant to qualify assumptions and justify limitations of the study.

As previously mentioned, the E.I. Wood Building has undergone continuing revisions to operating strategies and thus simulation and equipment profiling are difficult to model accurately. Upon further investigation of operating records, it was determined that implementation and continuing assessment of the various energy conservation techniques were not well documented. Further investigation with controls personnel familiar with building operation yielded insight into actual operational schedules.

Since individual metering of components is not incorporated into the building design, it is not possible to state how closely the results of the situation as it pertains to each individual component compare with actual percentages. However, the degree of accuracy of the overall simulation, and response of the model to operating strategy revisions, would argue for the claim that the model is likely an accurate representation of actual consumption.

Electrical consumption was modelled successfully with no major discrepancies. The same was not so for natural gas consumption. Actual natural gas consumption figures for the months of April and May are approximately 3 times the simulated value, to which building operators could not offer answers. Both the previous and following year's consumption values for the two months in question correlate with the computer generated value and since the 1981 April and May weather was warmer than the computer reference year, one must conclude that a significant operational procedure was varied, and unfortunately, not documented. The low December actual consumption was attributed to an early end of the month gas reading, resulting in an artificially shortened month.

Lighting levels were approximated, as, although delamping was in effect during 1981, additional delamping was continued in 1982. Maintenance staff acknowledge that delamping is an ongoing process, and exact lighting capacity at any time frame can only be estimated.

Load profiles for accessories inherently introduce error. Estimating exact electrical accessory loads such as clocks, calculators, typewriters, etc. is an approximation at best. An estimate of 0.32 watts per square meter was used. Electrical loads associated with car block heaters were not profiled as the

parking lot outlets are energized for two hours, only when ambient temperature is below -20°C. Parking lot lighting was combined with the percentage of lighting remaining at night, and represented a total lighting load of 11.5 kw.

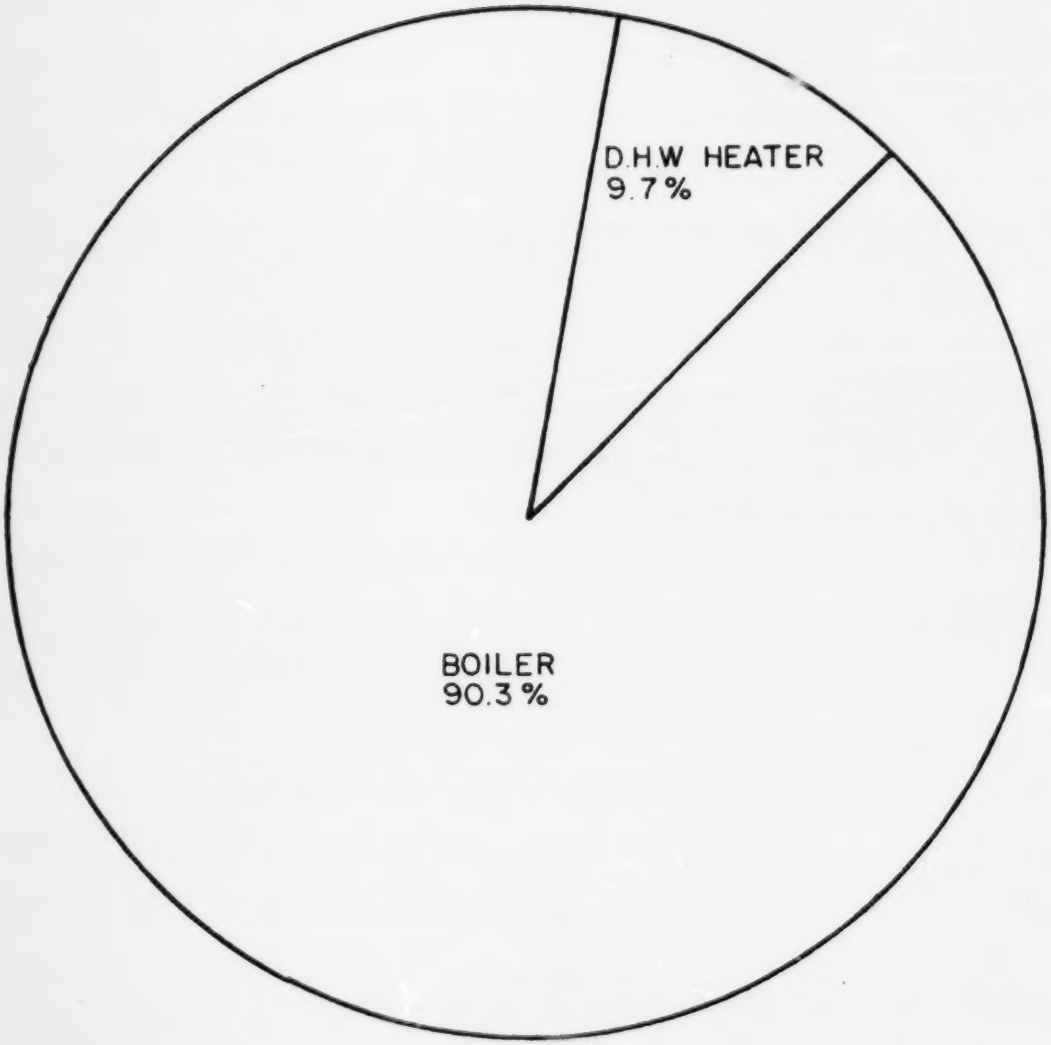
Kitchen consumption for both natural gas and electricity was also estimated, as kitchen accessories were not separately metered. Reasonable model results were obtained, as indicated by the near identical actual and simulated gas values obtained during the summer months when no heating energy is required.

When using referenced weather data, comparing actual consumption figures to simulated values introduces inherent error. Reference weather data is an averaged year compiled from twenty-five typical years. Therefore, the simulated year will have smooth general weather trends throughout the various seasons. Consequently, weather patterns for a specific year, in this case 1981, will deviate significantly from the computer's averaged values, resulting in contrasting consumption figures. Such deviations include atmospheric clearness or cloud cover, wind velocities, temperature lows and highs, and amount of rain and snowfall. These deviations can cause increases or decreases in both heating and cooling, affecting the total natural gas and electricity consumptions.

In assuming the overall simulation, the most significant discrepancy was clearly the anomalous natural gas consumption for the months of April and May. Various operational alternatives were simulated in an effort to model the high consumption levels, but none approached the actual values recorded. However, the match of simulated versus actual consumption levels, on an annual basis, was well within acceptable deviation, especially related to electrical consumption.

In numerous simulations carried out to date, the presence of anomalous consumption readings for one or two months has occurred frequently. In some instances, variable meter reading time periods can be the only viable explanation. In other circumstances, such as for April/May gas consumption data, the only logical conclusion relates to a significant modification to operating procedure. Unfortunately, building operations records invariably fail to provide sufficient clues to explain these discrepancies.

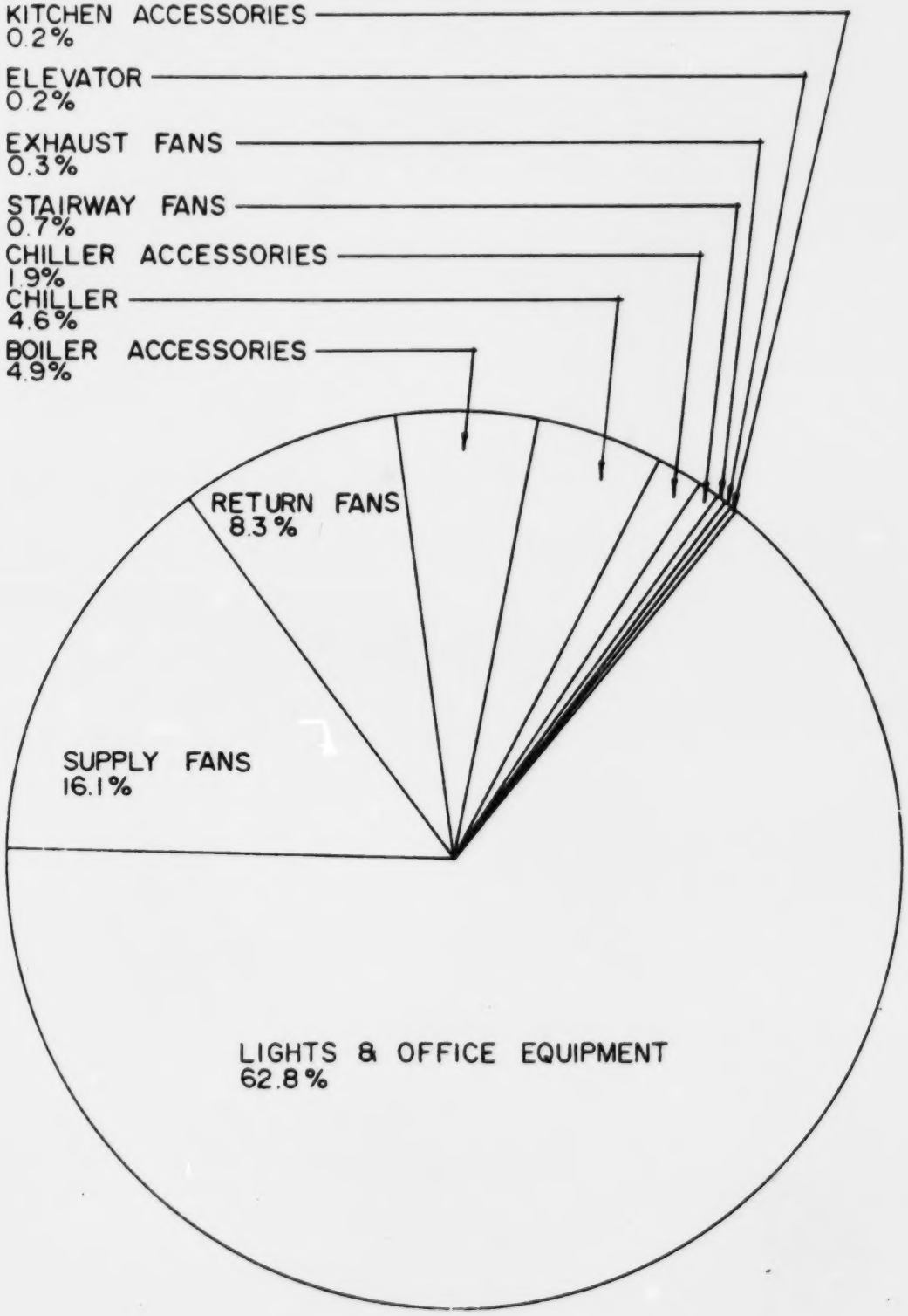
E.I. WOOD BUILDING
ENERGY CONSUMPTION BREAKDOWN



NATURAL GAS

E. I. WOOD BUILDING

ENERGY CONSUMPTION BREAKDOWN



ELECTRICAL

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE BELL CANADA ADMINISTRATIVE BUILDING
LONDON, ONT.

by

Peter J. Golem, P.Eng.
Chorley and Bisset Ltd.
London, Ont.

A STUDY OF THE BELL CANADA ADMINISTRATIVE BUILDING LONDON, ONTARIO

Peter J. Golem, Chorley & Bisset Ltd., London, Ontario

INTRODUCTION

This study was commisssioned by Division of Building Research, National Research Council. The intent of this study and companion studies funded by DBR is to support technology and information transfer in the area of office building energy conservation.

The Bell Canada Administrative Building is located in the downtown business and retail area of London, Ontario. The building was designed in 1979. Construction was completed by the summer of 1980.

The building consists of 14 levels. Nine levels are above grade and 5 below.

Above-grade: Ground Floor,
Office Floors 2,3,4,5,6,7,8

Below-grade: Court,
Parking Levels 1,2,3,4

The base of the building is essentially square, measuring about 75 meters on each side. Total gross floor area of the building is approximately 55,500 m^2 (597,500 sq. ft.). There are into three main areas:

Office Tower (Floors 2-8)	: 25,300 m^2
Ground Floor & Court Level	: 8,400 m^2
Parking Level	: 21,800 m^2

All discussion of building energy use will be based on working floor area, which excludes parking areas and mechanical rooms. Working floor area is essentially the net conditioned area in the building. For this building, the total is 33,700 m^2.

The walls of the building are of curtain wall construction using aluminum panels. Incorporated into the wall is 89 mm. of insulation (approximately RSI-1.85), a vapour barrier, and gypsum wallboard interior finish. Windows of the office tower are sealed insulating units with tinted glass (shading factor approximately 0.55). Interior shading is provided by venetian blinds. Windows account for about 27.5% of the gross wall area on the office tower. The ground floor is glazed with clear insulating units.

Total metered 1982 energy consumption for the entire building (including parking levels) was:

Electricity	:	6,795 MWH
Purchased Steam:		3,714 GJ
Natural Gas	:	842 GJ

Some adjustments were required to remove the energy consumption of the Parking Levels from the totals. We estimate that the actual 1982 energy consumption of the working floor area was:

Electricity	:	6,383 MWH (= 22,979 GJ)
Purchased Steam:		3,671 GJ
Natural Gas	:	425 GJ
		27,075 GJ

This corresponds to a unit energy consumption of about 800 MJ/m^2 per year.

Our analysis of energy use in the building identified eight principal energy uses. These are shown in Figure 1 as MJ/m^2 per year for each category. Total estimated energy consumption is 26,470 GJ or 785 MJ/m^2 annually.

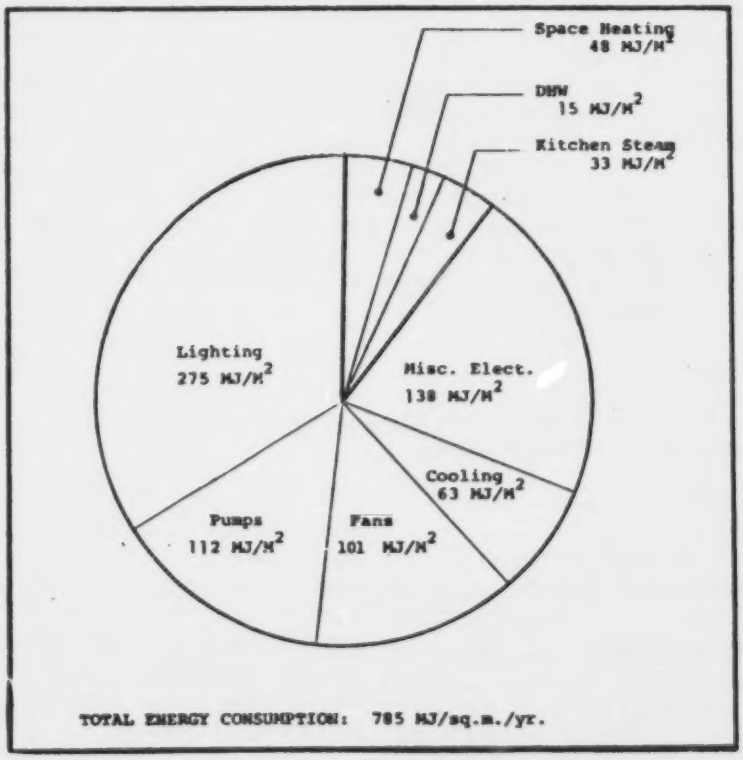


FIGURE 1: ESTIMATED BREAKDOWN OF ENERGY USE

A distinctive architectural feature on the South side of the building is an atrium above the cafeteria. The atrium is tilted at approximately 30 degrees from horizontal. It faces about 20 degrees East of South. Only about 50% of the atrium surface is glazed. Solar gains to the atrium space can be controlled by drapes which may be drawn below the atrium glazing.

Three pedestrian access points have revolving doors with small adjacent vestibule entrances. The West entrance is a vestibule entrance only. Access to the underground parking garage is through a lift door with card access. A floor sensor automatically closes the lift door. The office tower (Floors 2-8) contains very little full-height partitioning. Only the 8th floor has private offices. The four parking levels are private parking for Bell Canada employees.

The Court Level contains the cafeteria with its atrium space. The Kitchen is adjacent. Much of the remainder of the Court Level houses service departments. The central portion of the Ground Floor is the main building lobby overlooking the cafeteria. Much of the Ground Floor is retail and commercial space. The Ground Floor has a 6-day occupancy schedule.

Floors 2 through 8 house the various departments of Bell Canada. From a use and occupancy viewpoint, only the 4th floor is unique. This level contains the Telephone Operator Services (TOPS). There is a substantial amount of associated electronic gear. The TOPS area has continuous occupancy. However, the level of activity tends to be highest during normal business hours. Approximately 1050 people regularly work in the building.

BUILDING ENERGY USE

Three principal energy forms are brought into the building. These are:

Electricity	- For lights, fans, pumps, chillers, elevators, office equipment.
Purchased Steam	- For domestic hot water, kitchen, space heating backup.
Natural Gas	- For direct-fired makeup air units serving kitchen, graphics department spraybooth and parking levels.

BUILDING SYSTEMS

1. AIR HANDLING SYSTEMS

There are four main types of HVAC systems in the building serving a corresponding number of areas:

.1 Office Tower - Floors 2-8

The perimeter of the office tower is conditioned by a high pressure induction system, AHU-1. The supply air temperature is maintained high enough to heat the exposure with the greatest heat loss. Elsewhere, primary air is "recooled" in the induction units. AHU-1 is a mixed air system.

The core areas of the Office Tower are conditioned by cooling-only units (AHU-2 to 13 & 20). Most floors have two units. The 3rd floor has one unit. These are 100% recirculation systems.

.2 Ground Floor Tenant Units

Commercial tenant areas on the Ground Floor have simple mixed air systems (AHU-14 & 15 and FCU-11). All units have access to outside air, but there is no automatic control of outside air and return air quantities. Perimeter heating is accomplished by fin-tube radiation.

.3 Lobby and Court Level Units

The Ground Floor Lobby and much of the Court Level is conditioned by mixed air variable volume units (AHU-17, 18 & 19).

In addition, there are three direct-fired makeup air units. They serve the kitchen (FAU-2), a spray booth on the Court Level (FAU-3), and the parking levels (FAU-1). Some small areas such as the Building Control Centre are served by cooling-only fancoil units.

The four main types of air handling system are described in detail below:

1.1 AHU#1 - Primary Air Handling Unit

AHU#1 is the major source of heating, ventilation and humidity control in the building. This unit delivers primary air to induction units on the perimeter of floors 2 through 8. Refer to Figure 2.

Mixing dampers are modulated in response to the mixed air controller. An enthalpy economizer selects return air when outdoor air has a higher total heat content than return air. Minimum position is adjustable. A mixed air temperature controller maintains the mixed air temperature above 18°C. An occupied/unoccupied switch closes the outdoor air and relief air dampers when set to the unoccupied position.

A portion of the outdoor air passes through a heat recovery unit where it picks up heat from the sanitary exhaust. Design air quantities are marked on Figure 2.

The precoil in AHU#1 is a glycol coil connected through a heat exchanger to the secondary water return. The intent of the precoil was as follows. In winter, the heat exchanger was to recover heat from the secondary water/chilled water system. The precoil then acts as a preheat coil. In summer, when outdoor air temperatures are above the secondary water return temperature, the precoil was to serve as a "precool" coil.

The sprayed cooling coil is controlled to deliver air at 10°C in the cooling season. Air at this temperature is dry enough to accomplish dehumidification in the perimeter zones. The spray pump is available to provide humidification, and operates to control the relative humidity of return air according to a schedule reset from outdoor air temperature.

A discharge temperature controller modulates the heating coil valve. The discharge temperature is reset by a schedule responding to outdoor temperature.

1.2 AHU#2-13, 20 - Tower Core Units

The core areas of floors 2 through 8 are cooled and dehumidified by units located in core mechanical rooms on each level. All units except AHU#13 and 20 are 100% recirculation systems. AHU#13 and 20 are supplied with a fixed quantity (1180 L/s) of outdoor air. Refer to Figure 3.

Primary control of these units is by a discharge temperature controller. The discharge setpoint is reset over a narrow range by a space thermostat. The cooling coil has face and bypass dampers. When the outdoor temperature is below 18°C, all of the air passes through the cooling coil. Above 18°C, the bypass damper opens to 40%. The air quantity through the coil is reduced during the summer to improve the dehumidification characteristics of the coil.

AHU#2 and 3 on the 8th floor and AHU#13 and 20 on the 2nd floor are equipped with volume boxes. Inlet vanes mounted on the supply fans modulate to maintain a fixed pressure differential between the fan discharge and the conditioned space.

1.3 AHU#14 and 15 - Tenant Units (Ground Floor)

Tenant units AHU#14 and 15 are mixed air systems providing both heating and cooling by means of four-pipe fancoils. Perimeter heating in the space is accomplished by fin-tube radiation. AHU#14 and 15 serve ground floor commercial tenants on the West and North, respectively. Refer to Figure 4.

Return air is uncontrolled. Manual return air dampers are set 100% open. The outdoor air dampers are automatically controlled by a two position controller. The damper is fully open during the day and fully closed during unoccupied periods.

In the occupied mode, fan operation is continuous and a DAY space thermostat modulates the heating valve and cooling valve in sequence. In the unoccupied mode, a NIGHT thermostat cycles the supply fan to maintain minimum 18°C in the space.

FCU-11, another tenant unit, is similar to AHU#14 & 15. However, FCU-11 is equipped with a heat pump unit which allows it to fully condition the area even if the central cooling plant is off. FCU-11 serves a Trust Company which has longer business hours than other parts of the building.

1.4 AHU#17, 18 & 19 - Lobby & Court Levels

AHU#17, 18 & 19 are mixed air systems providing heating, cooling and ventilation. A primary function of AHU#17 is to reduce the pressure differential between the lobby and the outdoors. Refer to Figure 5.

Using an enthalpy contoller, the mixing dampers modulate open when free cooling is available, and close to minimum position when it is not. A mixed air temperature controller maintains the mixed air temperature above 18°C. The glycol heating coil valve and the cooling coil valve are modulated in sequence from a space thermostat.

In the unoccupied mode, the systems operate on 100% return air.

AHU#18 & 19 are full VAV systems. AHU#17 has variable volume control only on its return fan so that it can modulate in response to Lobby pressure.

2. CHILLED WATER, SECONDARY WATER & HEATING WATER SYSTEMS

There are three major liquid circulating systems in the building:

.1 Chilled water, CHW, serving all cooling coils.
.2 Secondary water, SW, serving induction units on the office tower primeter.
.3 Heating water, HW, serving all heating coils in the air handling units and perimeter radiation.

Chilled water is provided by two centrifugal chillers in the penthouse mechanical room. One of the chillers is a double bundle (heat pump) unit. The heat pump chiller is the primary source of heating water. Steam convertors are available as backup heating. The secondary water circuit serves the perimeter induction system. Return chilled water is normally used directly as secondary water. These systems are all shown on Figure 6.

Chiller #1 is a heat pump chiller and has priority over Chiller #2 which is a conventional centrifugal chiller. Chilled water is supplied at 6°C to cooling coils throughout the building. The chilled water return is diverted to the secondary water system and circulated by P-03 and P-04. The secondary water temperature must be no less than 13°C to avoid condensation of water vapour on the induction units (the units have no drains). Consequently, the CHWR stream is appropriately mixed with the SWR stream to keep the SWS stream above 15°C.

A water/glycol heat exchanger provides the opportunity for energy recovery from the SW stream before it returns to the chillers. The intention of the precoil in AHU-1 was to preheat outdoor air in the winter and precool outdoor air in the summer.

The heating water circuit passes through the secondary condenser of the heat pump chiller. Steam convertors are available to augment the heat pump when necessary. The secondary condensor bypass valve is set at 42°C. Higher entering temperatures would damage the chiller.

In the heating season, the tower bypass valve is controlled from the secondary bundle leaving temperature. Set at 41°C, chiller heat is rejected through the primary bundle and the cooling tower if ever the secondary bundle temperature becomes dangerously high.

In summer, the tower bypass valve is set at 35°C. Below this temperature, condenser water is simply recirculated. Above 35°C, condenser water passes to the cooling tower and the tower fans are stepped through low and high speed operation.

The perimeter air conditioning system is normally operated as a "recool" system. That is, primary air is the source of perimeter heating. Secondary water in the induction units recools as necessary. Valving in the secondary water circuit permits its alternate use as a heating circuit. Two-way valves shown with dark bodies in Figure 6 are normally closed. Changeover involves a reversal of the valve positions so that the secondary water circuit draws from the heating water circuit instead of the chilled water circuit.

3. LIGHTING

Lighting is a major component of the building energy consumption, accounting for about 35% of all energy.

Lighting operating energy has been minimized by two main methods:

.1 Lighting levels throughout the building have been designed conservatively.

.2 All lighting is under the control of the building automation system.

Lighting in most of the office tower (Floors 2-8) was designed at 18.3 W/m^2 (1.7 W/ft^2) average. This was achieved by installing a coffered ceiling-lighting system. The ceiling is laid out on a 1500 mm square grid pattern. Single-lamp flourescent fixtures are mounted along the centre line of each coffer. The pattern is broken periodically by building columns in the general office area. This type of lighting system normally provides an initial illumination level in the range of 700 lx.

Stairwells have fluorescent strip lighting. Elevator lobbies have suspended luminous ceilings with flourescent fixtures. Lighting levels in both these areas are less than half of the general office area.

Ground floor tenant areas are lit by suspended luminous ceilings with fluorescent fixtures. The main lobby and hallways on the Court Level have H.I.D. fixtures. There is some incandescent lighting in the cafeteria. Connected lighting on the Ground Floor and Court Levels has been designed at 11.6 W/m^2 (1.08 W/ft^2) average.

Lighting throughout the building is controlled from the building automation system.

4. BUILDING AUTOMATION SYSTEM

A Building Automation System was included in the original building design. The installed system is an ADT 7374 system.

The system form has a total capacity of 503 points although only about 300 points are currently used.
The breakdown is:

Control - Start/Stop/Enable	87 points
Status - ON/OFF indication	46 points
Analog - Temp. and Humidity	87 points
Alarm - Hi/Lo or Malfunction	74 points

All of the major air handling units are connected to the building automation system. The following functions have been included:

.1 Fan Control: Start/Stop control of the fans afford programming of system operating schedules.

.2 Occ/Unocc Control: Programmed control of occupied/unoccupied switches minimizes unnecessary introduction of outdoor air.

.3 Mixed Air Temperature Control: There are conventional pneumatic controls which regulate mixed air temperature. On AHU-1, 17, 18 and 19, the automation system can intervene. Such intervention is not programmed, but can be activated by keyboard commands.

.4 Supply Air Temperature Control: Like mixed air temperature, conventional controls routinely regulate supply air temperature. On AHU-1 manual intervention is possible.

.5 Spray Pump Control: Operation of the cooling coil spray pumps is normally programmed to the same schedule as the air handling unit.

.6 Temperature and Humidity Data: Various return air, mixed air and supply air conditions can be called up when required or printed out routinely with system log data.

Most of the major circulating pumps are controlled by the automation system. Pumps for the major hydronic systems are in parallel sets of two. One pump is always available as a backup. The automation system is used to alternate operation of the pumps on a daily basis.

Lighting on all levels of the building is controlled by the automation system. Lighting control is zoned as follows:

Floors 2-8 (each floor switched separately)	: 1. Perimeter 2. Northwest Core 3. Southeast Core
Ground Floor	: 1. Perimeter 2. Lobby 3. Exterior
Court Level	: 1. Cafeteria 2. Northeast 3. Northwest 4. Southeast 5. Southwest 6. Kitchen
Parking Levels	: 1. All Lighting

ENERGY EFFICIENT FEATURES

Several features of this building contribute to its efficiency. Some of these features have been looked at in detail. An attempt has been made to assess their cost-effectiveness. Energy cost avoidance is based on actual unit prices in effect in early 1983: 0.030 $/kWh for electricity and 8.50 $/GJ for purchased steam. It should be remembered that the following cost avoidance and payback estimates are specific to this building.

1. Heat Pump Chiller

Efficiently satisfying the heating and cooling requirements of zones with different exposures and uses is a fundamental problem. In this building the solution involves use of a perimeter induction system with heat recovery through a double bundle chiller.

Without heat recovery, a perimeter induction system would be quite inefficient. Via the heat pump chiller, heat recovered from areas with low heating loads is returned to the supply air and ultimately redistributed to areas with high heating loads. As noted previously the heat pump chiller normally meets the buildings heating requirements down to approximately -10°C. We estimate that this is a saving of about 3,700 GJ/yr, or $35,000.

Extra capital costs for the heat pump chiller system include the cost of the double bundle feature as well as the cost of oversizing all heating coils. Heating coils must be sized for entering water temperatures near 40°C instead of approximately 80°C. We estimate that additional capital costs are in the $90,000 range, providing a payback under 3 years.

2. Lighting

Lighting is the largest single energy consumer in the building. Even so, an annual lighting energy use of 275 MJ/m^2 is relatively low.

Lighting energy consumption has been kept low by two principal methods. Firstly, design lighting levels are low (18.3 W/m^2 in the Office Tower and 11.6 W/m^2 on the lower levels). Secondly, lighting is carefully controlled by the automation system.

Achieving reasonable lighting quality at low lighting levels required coffered ceiling/lighting systems. It has been customary to design convential systems (T-Bar with recessed fixtures) at 25 to 30 W/m^2 or higher. Based on a reduction of 10 W/m^2, the cost avoidance in this case is about $1.40 annually. This includes lighting energy, cooling energy and electrical demand (both lighting and cooling).

Installation of a coffered ceiling/lighting system involves a cost premium of about 10$/$m^2$. However, the cooling plant can be downsized. We estimate a potential capital cost savings of 1.35 $/$m^2$. Thus, the net capital cost premium is about 8.65 $/$m^2$ and the payback is near 6 years.

3. VAV Air Handling Systems

Three major air handling units (#17, 18 & 19) on the lower levels are VAV systems. Variable air volume systems are efficient because they modulate the air quantity in response to zone requirements. This minimizes the amount of air which needs to be heated or cooled and so saves heating, cooling and fan energy.

The capital cost premium for a VAV system is variable. However, compared to terminal reheat system, a capital cost premium of perhaps 6 to 10 $/$m^2$ might be anticipated. Corresponding energy cost avoidance is estimated to be in the 2.50 $/$m^2$ range, giving a payback in about 3 years.

4. Sanitary Exhaust Heat Recovery

We estimate the value of energy recovered by the sanitary exhaust fan to be near $3100 annually. The fan operating energy cost is about $160, reducing the net savings to under $3000 annually. The capital cost of the heat recovery system would be in the range of $15,000. Payback on the heat recovery system is then about 5 years.

5. Building Automation System

Of the 300 total points, about 100 are dedicated to energy Management tasks. The principal advantage of the automation system is that system operating hours can be strictly controlled. Alternatives such as manual control or a distributed system of time clocks would not be able to maintain as tight control on operating hours.

We have assumed that system operating hours might increase by 15 to 20% if a central automation system were not used. Associated energy consumption is 2750 GJ/yr and annual cost avoidance is about $21,000.

The total cost of automation systems such as this is in the range of $900 per installed point. The 100 Energy Management points then cost approximately $90,000. Payback period is about 4.5 years.

6. HVAC System Controls

All air handling units are equipped with energy efficient control features. We did not attempt to evaluate the cost effectiveness of these features. Normally, however, these features can be easily justified, especially in new construction:

.1 Sequenced heating and cooling coil valves to minimize simultaneous heating and cooling.
.2 Resetting supply air temperature (AHU#1) to minimize "recooling".
.3 Occupied/Unoccupied switches to limit entry of outdoor air when the building occupancy is low.
.4 Mixing damper economizers to move outdoor air dampers to minimum position when free cooling is not available.

7. Architectural Features

Certain architectural features contribute to the energy efficiency of the building.

.1 Low window area (less than 30% of gross wall).
.2 Double glazing greatly reduces heating requirements.
.3 Tinted glass reduces perimeter cooling requirements.
.4 Well insulated walls.
.5 Revolving doors & vestibules minimize entry of outdoor air.
.6 Low surface/volume ratio complements the heat pump chiller system.

CONCLUSIONS

The various energy efficient features relate to between 12,000 and 15,000 GJ/year of avoided energy consumption. Had these features not been incorporated into the building the annual energy cost for the building would have been increased by over $100,000. The unit energy consumption of the building would have been in the range of 1100 to 1200 MJ/m^{2}yr, or about 50% above the present value.

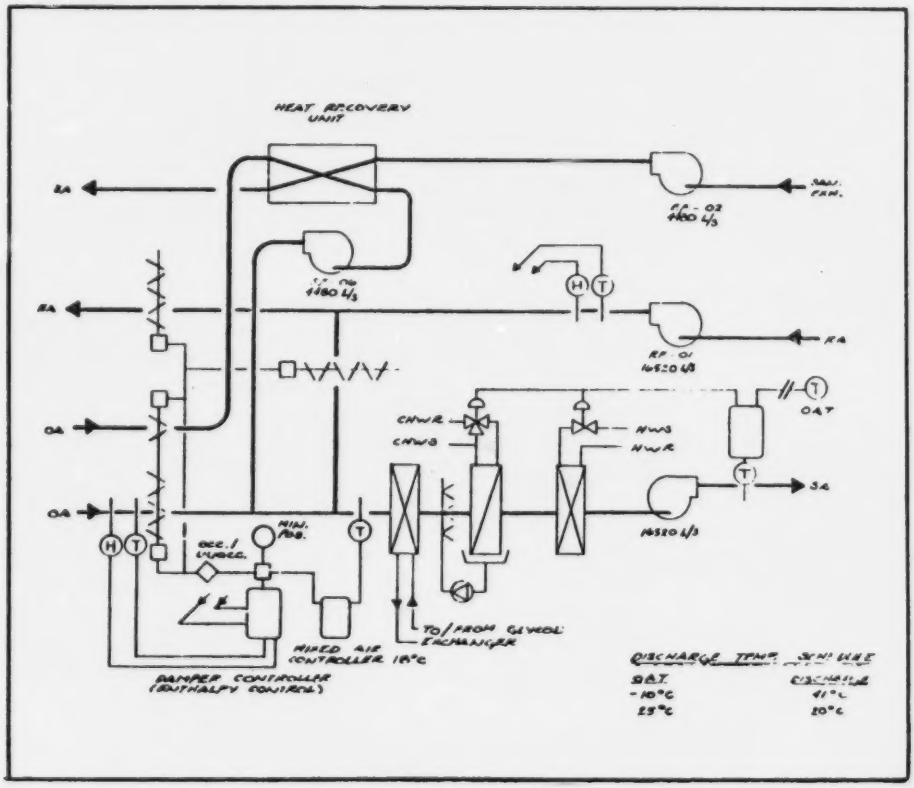


FIGURE 2: AHU#1 PRIMARY AIR HANDLING UNIT (TOWER PERIMETER)

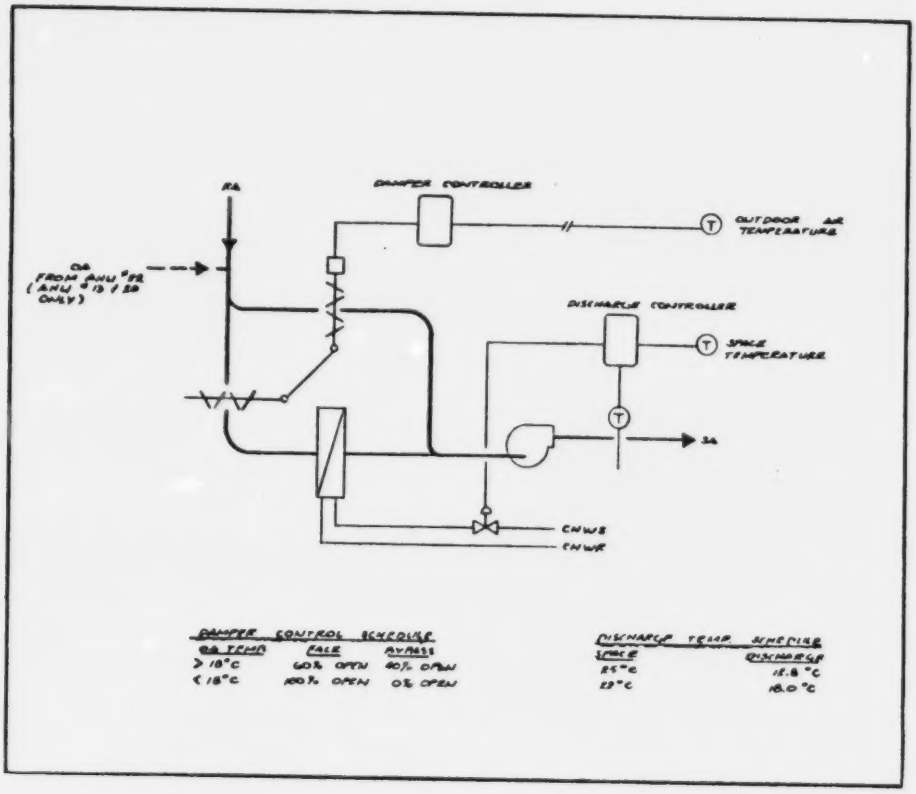


FIGURE 3:
TYPICAL TOWER
CORE A/C SYSTEM

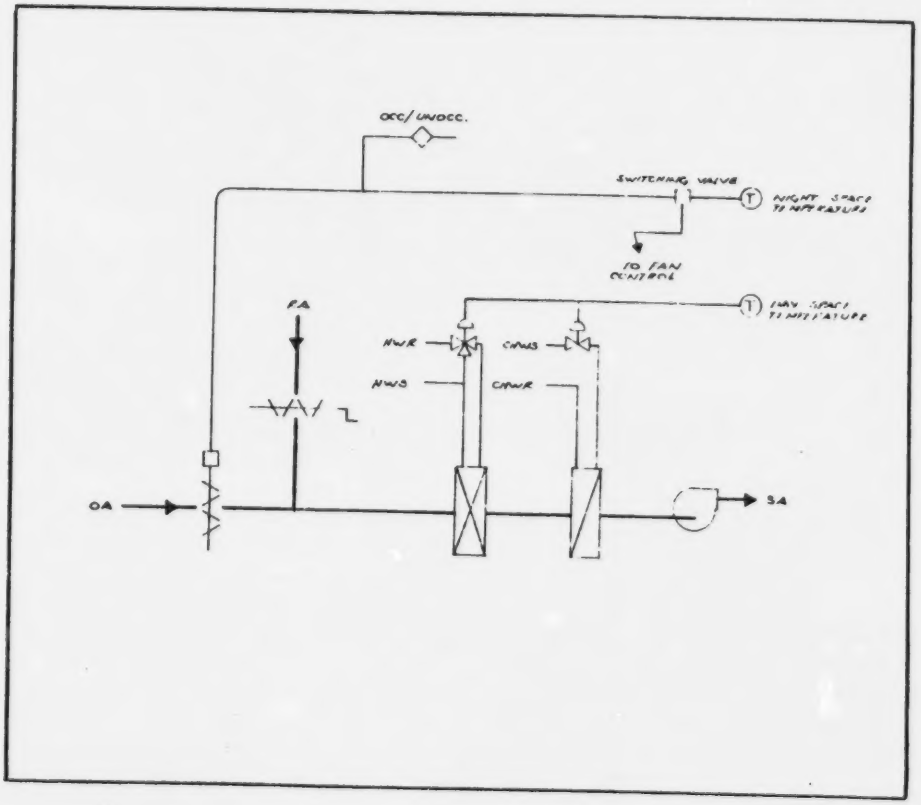


FIGURE 4:
TYPICAL TENANT
AIR HANDLING
SYSTEM ON
GROUND FLOOR

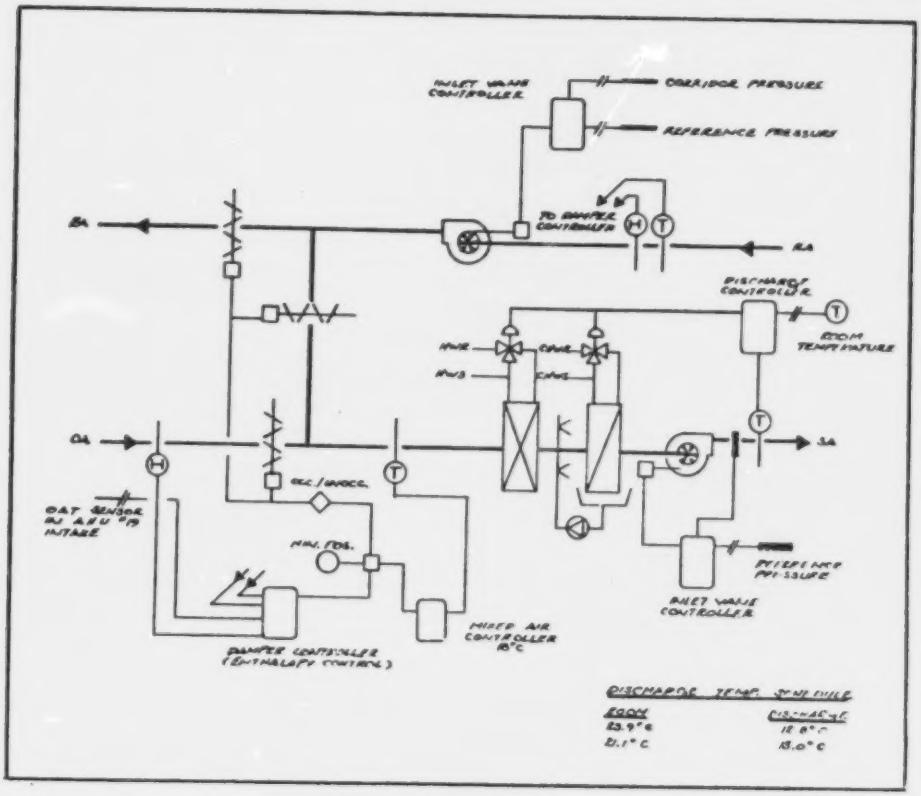


FIGURE 5:
TYPICAL COURT LEVEL AND LOBBY AIR HANDLING SYSTEM

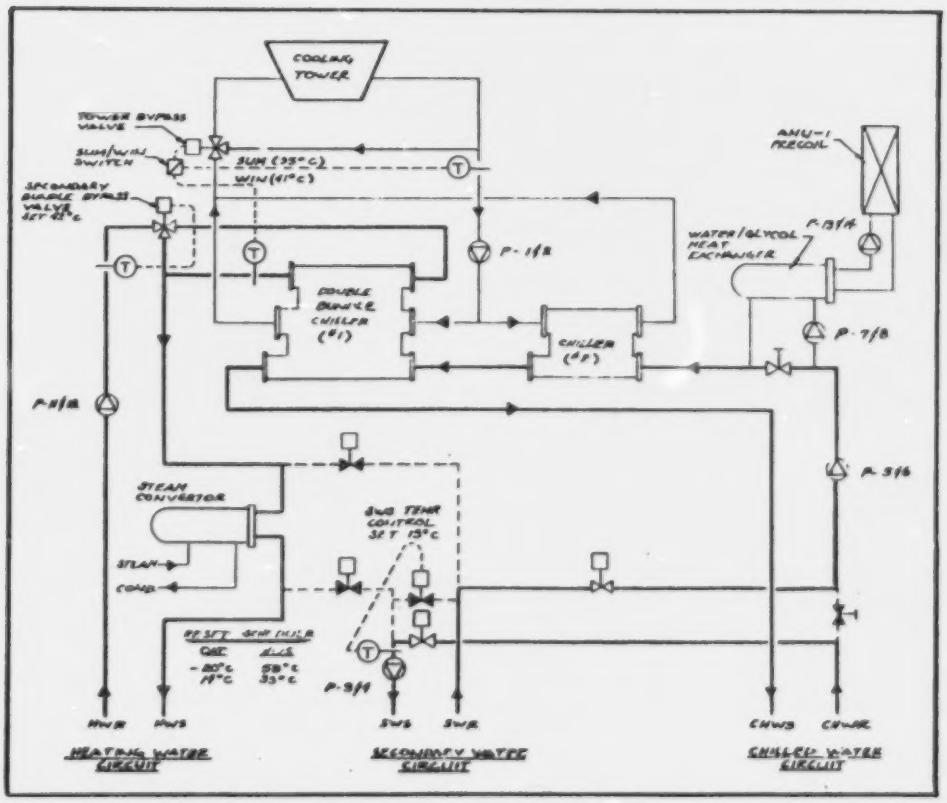


FIGURE 6:
CHILLED WATER SECONDARY WATER AND HEATING WATER SYSTEM

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE JOSEPH SHEPARD BUILDING
NORTH YORK, ONT.

by

Alan Kobayashi, P.Eng.
Giffels Associates Ltd.
Toronto, Ont.

STUDY OF ENERGY CONSERVATION FEATURES JOSEPH SHEPARD BUILDING GOVERNMENT OF CANADA OFFICES NORTH YORK, ONTARIO

A.M. Kobayashi, P. Eng.
Giffels Associates Limited

ABSTRACT

Energy consumption figures for office buildings vary greatly. Buildings with lower consumptions contain unique features which separates them from the others. The energy efficient Government of Canada offices (Joseph Shepard Building) in North York, Ontario is examined and its energy conservation features along with their impact on the annual consumption figure are discussed.

INTRODUCTION

Annual energy consumption values for office buildings in Canada can range between 600 and 5400 MJ/m^2 yr. The wide variance indicates that some buildings possess unique features which make them consume more energy than can be rationalized by different climatic conditions. The identification of these features and their impact on the annual energy consumption figure provides useful information which can be potentially utilized in other structures.

The Joseph Shepard Building (Federal Government Offices) in North York, Ontario has an average annual energy consumption of 782 MJ/m^2 yr. since its construction in 1977. Originally designed to be energy efficient, the building is an excellent example for study.

BUILDING DESCRIPTION

The Joseph Shepard Building is a 77,500 m^2 office building housing various Government of Canada departments. The structure is composed of thirteen office and public area floors above grade, two parking levels below grade and a penthouse mechanical room.

The exterior shell consists of brick and block spandrel wall and hermetically sealed, thermally broken clear double glazing. On selected exposures, the glass area has been reduced and replaced with insulated metal panels.

Cooling is achieved with two centrifugal chillers, one of which contains heat reclaim capabilities. Heating for the first and second floors and parking garage are handled with hot water generated by packaged gas fired boilers. Perimeter heating for the third to thirteenth floors is serviced by heat reclaimed from the interior zones. Four thermal storage tanks allow either chilled or heating water to be stored.

Lighting is designed to suit the area use thus providing adequate illumination levels with minimal electrical consumption.

ENERGY DISTRIBUTION

Calculations, verified by actual energy bills, indicate that the Shepard Building consumes an average total of 781.6 MJ/m^2 yr. of natural gas and electricity in its operation. This figure includes the occupied office and public space within the building. Underground parking garages, which are heated, have been omitted from this calculation.

The following breakdown was produced utilizing a combination of manual methods and dynamic computer simulation.

	MJ/m2 yr.	%
Lights	363.5	46.5
Elevators	18.6	2.4
Fans	48.0	6.1
Pumps	56.6	7.2
Internal Equipment	50.4	6.5
Kitchen - Electric	2.3	0.3
Kitchen - Gas	0.8	0.1
Heating	117.0	15.0
Cooling	109.7	14.0
Domestic Hot Water	13.6	1.7
Miscellaneous	1.1	0.2
TOTAL	781.6	100.0

ENERGY CONSERVATION FEATURES

An energy budget was established for the Joseph Shepard Building during the early design stages. In order to accommodate this budget, as well as to produce an architecturally acceptable and pleasing structure, the design team incorporated numerous features which contributed to the overall reduction in energy consumption.

Through study and analysis of the building and its systems, these energy conservation features were identified. The extent of these items included both system arrangements and operating procedures.

Some of these features have become commonplace in current building design and operation. There are, however, significant numbers of new buildings still being built without many of these items and numerous

existing structures being operated in the same manner as initiated after construction. Ir these instances, the energy conservation features incorporated in the Joseph Shepard Building may be considered.

Descriptions of these features and their predicted impact on the building's energy consumption are presented herein. In many cases the identified item is compared to alternate design practices to illustrate the magnitude of the change. Energy reductions were calculated utilizing a combination of manual and dynamic computer simulation methods.

1. Task Lighting Design Used to Reduce Lighting Consumption

Typical office building lighting in the past was composed of a geometrically arranged array of fixtures providing a uniform illumination level of 968 to 1076 lux in all areas of the occupied floor. The fixture arrangement produced an attractive aesthetic appearance while the high level of intensity allowed unlimited rearrangement of the interior layout. The system was appealing in all aspects except energy consumption, where it proved to use substantial amount of electricity.

While a uniform intensity of 968 to 1076 lux is more than adequate for most tasks it is not necessary in corridor, aisle or other general areas. The concept of task lighting recognizes this fact and illuminates only the workstations.

Task lighting was utilized throughout the office areas of the Joseph Shepard Building. In order to further reduce energy consumptions, intensity levels were dropped to an average 807 lux over workstations. It was found that even with this reduction, an agreeable environment was

provided. To accommodate the necessity for flexibility, a plug in grid system was installed allowing lights to be easily relocated. The conduit header system was buried in the structural slab to minimize congestion within the ceiling space.

On the average, the use of task lighting has reduced installed wattages by approximately 42% from a potential 43.1 W/m^2 to 24.8 W/m^2. As fine tuning progresses and furniture layouts become optimized, this figure may be lowered further.

The reduction of installed wattage lowers direct lighting electricity consumption and also serves to reduce the cooling load and hence electricity consumption associated with the chiller operation. Supply air temperatures may be increased or alternately air volumes decreased.

Energy Consumption Reduction: 220.9 MJ/m^2 yr.
Existing Condition: Lighting load of 24.8 W/m^2
Alternate Conditions: Lighting load of 43.1 W/m^2

2. Lighting Fixtures Delamped to Suit Application

The Shepard Building office area lighting is divided into two systems; an overhead task lighting system and a column cornice installation. The overhead system accounted for approximately 21.5 W/m^2 while the cornice lighting contributed 5.38 W/m^2 at the time of design. The column lighting was originally intended to act as a low level illumination source for the cleaners and as security lighting during unoccupied hours when the overhead fixtures were turned off. It was found, however, that dark spots developed due to partitions and it was decided to leave the entire lighting system on while the cleaners worked.

Since the cornice lighting was now used only for night security, delamping was performed. This lowered the connected load to 3.2 W/m^2. The reduction of installed wattages lowers direct lighting electricity

consumption and also serves to reduce the cooling load and hence electricity consumption associated with the chiller operation. Supply air temperatures may be increased or alternately air volumes decreased.

Energy Consumption Reduction: 69.8 MJ/m^2 yr
Existing Conditions: Lighting load of 24.8 W/m^2
Alternate Condition: Lighting load of 26.9 W/m^2

3. Lights are Shut Off During Unoccupied Hours

In many office buildings, cleaners begin work at an hour when most of the employees have left for the day. Lights are left on until all the cleaning is done, and then in some instances the lights are turned off. Other times the lights may be left operating all night.

Cleaners in the Shepard Building start at an earlier hour and work around the office employees. At night, as they work from floor to floor, lights are shut off upon completion of cleaning. In this way, lighting operating time and hence electrical consumption is reduced. Although the exact amount of time for cleaning varies from night to night, an approximate estimate is that two hours of lighting operation per weeknight is saved with this system.

An alternate effect of reduced lighting hours is the reduced amount of heat which is stored within the structure. Although the contribution to the load source is minimal, it none the less aids in lowering air conditioning requirements.

Reduction of lighting operation was studied in two parts. The first was to calculate the energy consumption reduction obtained by not operating the lights all night. The other was to determine the effect of operating the lights for two hours less per weeknight.

Energy Consumption Reduction: 418.5 MJ/m^2 yr.
Existing Conditions: Lights shut off as cleaners finish work.
Alternate Condition: Lights on continuously.

Energy Consumption Reduction: 77.5 MJ/m^2 yr
Existing Conditions: Lights shut off as cleaners finish work.
Alternate Conditions: Light operation increased by two hours.

4. Double Glazing Installed in Lieu of Single Glazing

Numerous office buildings were in the past built with single pane glazing. Although the material is lower in capital cost than double glazing, its thermal resistance qualities are considerably less and hence heat losses and gains are substantially higher. This in turn increases building energy consumption.

The building studied utilized double glazing exclusively thus creating a higher quality building envelope. The glazing installed was Galverbel Sealtite, composed of 0.48 cm clear pane, 1.27 cm air space and 0.48 cm clear pane.

Energy Consumption Reduction: 48.1 MJ/m^2 yr.
Existing Condition: Building with double glazing.
Alternate Condition: Building with single glazing.

5. Adjustable Vertical Blinds Used for Internal Shading. Blinds are Perforated to Allow Limited Vision Even when Closed

Adjustable vertical blinds are installed on the interior surface of the exterior building glazing. Their function is similar to that of venetian blinds; to reflect solar heat gain back out of the window thus reducing cooling loads. The blinds utilized are perforated allowing limited vision even when completely closed.

The operation of the blinds is on a manual basis and therefore susceptable to the whims of the occupant. They do, however, provide a source for internal shading.

Observations indicate that the blinds reduce heat gain substantially. The building operator noted that one year he had a member of his staff close off all the blinds on Friday evening after the occupants had left for the day. Observed space temperatures prior to cooling start-up on Monday morning were noticeably lower than when the blinds were left open.

Energy Consumption Reduction: 1.2 MJ/m^2 yr
Existing Condition: Glass shading coefficient of 0.77
Alternate Condition: Glass shading coefficient of 0.83

6. Air Handling Units Turned off During Unoccupied Hours

The building utilizes the compartmentalized approach to supply air distribution. Consistent with this, two air handling units serve each of the 13 above grade floors. In addition, there are two main ventilation supply units located in the penthouse mechanical room.

The air handling units and associated sanitary and other exhaust fans are shut down automatically by the building automation system. Energy savings were established through reduction in fan motor usage and chiller operating time.

Energy Consumption Reduction: 197.6 MJ/m^2 yr.
Existing Condition: Air handling units shut off during unoccupied hours.
Alternate Condition: Air handling units operated continuously.

7. Air Conditioning Systems Started in Sequence Instead of Simultaneously to Reduce Electrical Demand

The building automation system sequences the start-up of air handling units and associated fans to reduce electrical demand.

Although this feature does not save in energy consumption, it does reduce electrical demand.

Energy Consumption Reduction: Electrical demand reduction.

8. Smaller Local Air Handling units Used in Lieu of Larger Centrally Located Units

Typical office building design in the past utilized large centrally located air handling units to distribute supply air through a system of vertical risers and branch ductwork. These units handled large amounts of air against high static pressures (i.e. 1.5 to 2kPa).

The Joseph Shepard Building has smaller units located on the floors served. By doing this, air distribution energy requirements are reduced and demands are lowered. Also, operational versatility is increased allowing segmented portions of the building to be conditioned while the remainder is shut down.

Energy Consumption Reduction: 112.4 MJ/m^2 yr.
Alternate Conditions: 15% larger motor capacity.

9. Ventilation Air Quantities Reduced

Ventilation air quantities vary from building to building, however, generally are maintained between .508 L per sec/m^2 and 1.02 L per sec/m^2 during occupied hours.

Ventilation in the Shepard Building is handled by two large air handling units in the penthouse mechanical room. The systems are balanced to provide 11% outside air to each supply air handling unit. This translates to approximately .457 L per sec/m^2.

The systems do not make use of outside air when this can reduce chiller operating time. It was found that in winter, the heat generated within the interior zones was better used to heat the perimeter.

Energy consumption reductions were based on the additional sensible load in summer.

Energy Consumption Reduction: 20.2 MJ/m^2 yr.
Existing Condition: 11% outside air introduced for ventilation.
Alternate Condition: 20% outside air introduced for ventilation.

10. Variable Air Volume Utilized for Zone Control. Simultaneous Heating and Cooling Eliminated

Supply air distribution to the space is controlled by varying the air volumes to each zone. Minimum volume set point on each zone variable volume box varies between 0 to 35% with the former figure being in the majority. In most cases however, the lights create a base cooling load which will always be present during occupied periods thus preventing complete shut off of air delivery.

The variable volume concept allows individual zone control without the requirement for supply air reheating. Although providing extremely good zone control, reheat is wasteful due to use of simultaneous heating and cooling, under partial load conditions.

Energy Consumption Reduction: 139.9 MJ/m^2 yr.
Existing Condition: Variable volume
Alternate Condition: Constant volume, terminal reheat with scheduled cold coil discharge temperature during cooling.

11. Heat Reclaim Chiller Utilized to Allow Interior Heat to be Used to Handle Perimeter Loads

In large office buildings, the perimeter zones (those with exterior exposures) are susceptible to load changes corresponding to variances in outside air temperature and solar heat gains. These zones require heating in the winter, cooling in the summer and a combination of heating and cooling during the transition seasons. Interior zones on the other hand require cooling all year since more heat is generated internally within the zone than is lost.

During the heating season, some office buildings utilized boilers to handle the perimeter heat loss and mechanical refrigeration to cool the interior. In other structures the boilers were operated, but the mechanical refrigeration was shut down, and cold outside air was used to provide the cooling. The reduction in chiller operating time reduced electricity consumption and operating costs.

Both of the above concepts, however, are based on the same premise of utilizing energy to heat the perimeter while, at the same time, rejecting heat from the interior to the atmosphere.

The Shepard Building, through a heat reclaim double bundle condenser chiller, uses the heat from the interior to handle perimeter skin loads. In this way, energy entering the building is efficiently utilized.

Energy Consumption Reduction: 31.8 MJ/m^2 yr.
Existing Condition: Heat reclaim chiller provides part of the heating load.
Alternate Condition: Gas fired boilers provide all heating.

12. Thermal Energy Storage Used to Reduce Energy Consumption and Demand

Thermal energy storage is an effective way in reducing both energy consumption and demand. With the thermal energy reservoir, instantaneous demands are reduced thus allowing smaller equipment sizes to be selected. The smaller pieces of equipment operate closer to full load conditions for longer periods thus yielding a higher level of efficiency. Energy which is not used to meet instantaneous loads may be stored and used at a later date.

The Joseph Shepard Building has four concrete storage tanks, housing a total of 1,135,624 L of water. The tanks contain moveable baffles so that supply and return water are separated. The elimination of mixing allows a higher quality energy source to be available. Tank piping and valving allow the system to store either heating or chilled water, depending on the season.

The installation of the storage facilities increases the versatility of the heat reclaim chiller, allowing storage for the heat produced.

Energy Consumption Reduction: 65.9 MJ/m^2 yr.
Existing Condition: Overall chiller efficiency improved by 10%. Storage tank capacity available for unoccupied heating.
Alternate Condition: No storage facilities. Chillers sized to handle peak load.

CONCLUSIONS

Some of the energy conservation features identified within the Joseph Shepard Building have excellent potential for implementation in other existing office buildings.

Items which are "built in" from original construction are generally not practical to implement on a retrofit basis even though they reduce energy consumption. These items, however, may be considered for new buildings.

AK:aw:A40

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE RED DEER PROVINCIAL BUILDING
RED DEER, ALTA.

by

Reg Monteyne, P.Eng.
Vinto Engineering
Edmonton, Alta.

INTRODUCTION

The Public Works Division of the Alberta Government introduced design requirements for public buildings in 1977. One of the design requirements was that buildings greater than 1000 m^2 in floor area would be designed in a manner that would limit building energy consumption to no more than 300 kWh per m^2 per year or 1080 MJ per m^2 per year. The Red Deer Provincial Building which I will be reporting on today was the prototypical example from which many of these design requirements including the energy budget were established and justified.

This building was designed and tendered in 1977. The Prime Consultant and Architect for the project were the firm of O'Connor, O'Connor & Maltby, the electrical consultant was Allsopp Morgan Engineering Ltd. and the mechanical engineering was performed by Alberta Public Works personnel.

The building was subjected to detailed design analysis including a computer simulation of energy comsumption using the Meriwether program. That analysis predicted that the building energy consumption would be 290 kwh per m^2 per year or 1044 $MJ/m^2 \cdot yr$.

The building was tendered in December, 1977. The total cost of the building was $9,700,000. or $441./m^2$ excluding the parkade area. These costs include a completely outfitted building with all tenant improvements. In comparison to other buildings constructed in Alberta at that time, the construction cost for this building was no higher than other similar structures. It could be assumed that a relatively efficient office building could be designed and constructed for little or no premium to capital costs.

I feel it is also worthwhile discussing the difficulty which we had in meeting the requirements of the National Research Council request for proposal. It would appear that in Alberta at least, there are very few office buildings that have been in operation for more than 2 years which met the energy consumption criteria. Apparently, the other consultants represented at this seminar did not encounter these difficulties in locating suitable buildings in their geographical areas. This indicates to us that Alberta lags behind the rest of Canada in energy efficiency of buildings and in all probability, this is a result of significantly lower energy prices. It also appears that Governments, both Federal and Provincial, are leading the way in energy efficient buildings. The majority of buildings represented at this seminar are government and quasi-government buildings. These buildings will provide excellent examples of efficiency in design and operations. These buildings establish the bench mark for other existing and new buildings.

GENERAL DESCRIPTION OF BUILDING

The Red Deer Provincial Building was partially occupied in January, 1980 and fully occupied and operational since May, 1981. The building has a net floor area of 20,500 m^2, a 4800 m^2 underground parking garage and is 6-storeys in height. The building contains the regional offices of various provincial government departments and agencies. The usage of the building is strictly office oriented tasks and there are no unusual energy consuming loads such as kitchen/cafeterias or computer rooms.

The office layout on each floor is a combination of perimeter offices with full height partitions and open space planning on the interior areas of each floor.

SITE DESCRIPTION

The building is located in an urban area, downtown Red Deer, a city of 40,000 people. The building orientation is in the north/south direction. The building has a large footprint on its site and consists of a 2-storey portion, a 4-storey portion and a 6-storey portion.

ARCHITECTURAL DESCRIPTION

The exterior wall of the building is predominately a precast concrete cladding with 40 mm of rigid styrofoam insulation on a drywall backing and steel strapping. This wall was calculated to have a "U" value of .40 watts/m^2 ^oC. There is also a limited amount of spandrel glass curtain wall which was calculated to have a "U" value of .39 watts/m^2 ^oC. The detailing of air/vapour seal in exterior walls was noted. Barrier is continuous at window opening roof and wall junctions and at penetrations through the envelope. Barrier consists of 4 mil polyethylene sheet laminated between two sheets of drywall.

The exterior glazing is double glazed with a medium solar bronze pane on the exterior and a clear pane on the interior. Glazing is provided with drapery which is an open weave design of medium colour. The glazing has a "U" factor of 3.07 watts/m^2 ^oC and a shading coefficient of .51 was assumed. Overall, the glazing consititutes 28% of the exterior wall area. The roof is a standard built-up roof and has a "U" factor of .52 watts/m^2 ^oC.

MECHANICAL SYSTEM DESCRIPTION

The building is heated by hot water perimeter radiation and unit heaters. The hot water is heated by natural draft gas-fired boilers and pumped throughout the building.

The building cooling system is a chilled water plant with centrifugal chiller and induced draft cooling tower.

Ventilation and space cooling is provided by variable air volume systems. These systems consist of a mixed air plenum using the "economizer" principle, a cooling coil and variable pitch in motion axial supply and return air fans. The variable volume terminal units at the space level are allowed to shut off completely in interior spaces. The perimeter terminal units can only reduce to 25% of design air volumes.

The domestic hot water for the building is provided by gas-fired hot water storage heaters.

The parking garage is ventilated by a direct fired natural gas make-up air unit and is exhausted to the outdoors. It is interesting to note that the original design incorporated a glycol run around heat recovery system for parkade make-up air and exhaust, but this system was not in operation because subsequent Alberta Government studies revealed that it was not economical to recover this energy at this point in time.

ELECTRICAL SYSTEM DESCRIPTION

The lighting system designed for Red Deer Provincial Building consumes a maximum of 22.6 watts/m^2. The lighting design consists of a 1' x 4' light fixture in a 4' x 4' coffered ceiling. The power distribution for the building is 600 volts, mechanical equipment motors and elevators; 347 volts power to lighting system and 120 volts to office space power point. An allowance for miscellaneous office equipment of 5.4 watts per square metre was incorporated in the design. There are 4 elevators with a peak power load of 90 kW.

OPERATIONS DESCRIPTION

The building is operated and maintained by Alberta Government Services and a full time building superintendent is in charge of the building. We met with him to confirm the present status of the building systems and operating schedules.

The building operating profiles for lighting, occupancy, air systems and cooling systems were established from our discussions with the superintendent. Figure copies of the profiles used are included with this paper as 1 to 9 inclusive. The building was surveyed at night to verify shut-off schedules established.

The site investigation also served to confirm that the original drawings and original system intent was put into effect in the construction and operations stage.

ANALYSIS STAGE

After assembling the descriptive data about the building, we needed to determine how and where the energy was used in this building. Separate metering of various energy uses was not available so a computer simulation using the Meriwether program was undertaken.

A comparison of the simulated total energy consumption and actual energy used provided a reasonable correlation.

A breakdown of the energy usage of the building into various components is attached. See Table 1 and 2 for numerical breakdown and Figure 10 and 11 for graphical breakdown.

An analysis of the Red Deer Provincial Building revealed 5 areas which were felt to be significant factors in reducing the energy consumption of this building to a level considerably below the norm for Canadian office buildings.

The first of these factors which was identified was the extremely good part load performance of the variable pitch in motion axial fans.

The second significant factor was the low overall lighting power density required to achieve effective building lighting.

The third important point is the rigid control of systems operations and, in particular, rigid operating hours of fan systems, parkade systems, lights and cooling systems.

The fourth area which we felt was significant, particularly in a winter climate such as Red Deer which has a design temperature of $-35^{o}C$ and over 5800 heating degree days, was the attention and detailing paid to achieving an air seal for the building. We expected that this reduced air infiltration to a large extent.

In order to measure the impact on the building's overall energy consumption of each of these features, it was necessary to analyze what would be the more standard or normal procedure that would be expected in a conventional office building.

In a typical office building one might expect to find a variable volume ventilation system but the fan volume control would, in all likelihood, consist of variable inlet vanes. These vanes do not produce the same type of part load operating efficiency as do the variable pitch in motion fans. Using the computer simulation we predicted that the Red Deer Provincial Building energy consumption would increase by 35 MJ/m^2/year or 4.1% if inlet vanes had been installed.

The lighting power density in a standard lighting system providing equal lighting quality might consume as much as 32 watts per m^2 at 100% load. The effect of an increase in lighting power requirements from 20 watts per m^2 would be a 7.2% increase in total energy consumption or 62 MJ/m^2/year.

Typically, an office building operating hours are not as rigidly controlled as the Red Deer Provincial Building. In many cases lighting and ventilation systems are left on until janitorial work has been completed. As an average, we assumed a building might operate 13 hours per day in lieu of 10 hours per day at the Provincial Building. The effect of this additional 3 hours per day, Monday to Friday, represents a 1.7% increase in energy consumption or 15 MJ/m^2/year.

Air infiltration into a building is difficult to quantify and its effects on energy consumption equally difficult to determine. We would expect that the attention to details and air sealing on the Provincial Building would result in a "tight" wall construction. Normal construction detailing and practices on a typical building would result in a "average" wall construction.

Using equations developed by National Research Council, we estimated the difference in peak air infiltration rate between these two qualities of wall construction.

The effect of increasing air infiltration by relaxing the details incorporated into the Provincial Building design turned out to be quite dramatic. Energy consumption would increase by 40 MJ/m^2/year or 4.6%.

The net result of these four factors which were assumed to be mutually exclusive of each other would be an increase in the Red Deer Provincial Building energy consumption of 152 MJ/m^2/year or 16.5%.

CONCLUSIONS

The Red Deer Provincial Building is not that unusual when compared with other office buildings. It is a building constructed with relatively conventional systems.

These systems did not have an increasing effect on the capital cost of the building when compared with other similar structures. The designers of the building produced a product which was relatively efficient when compared to other buildings offering similar internal environments. It is possible within conventional technology to make significant reductions in energy consumption of office buildings through design analysis, design details, competent constructors and aggressive operations policies.

The Red Deer Provincial Building has also provided the Alberta Government with a proven example which justifies the energy budgets established in their design requirement and has provided valuable insight that further reductions in these energy budgets are quite achievable.

In fact, based on success like Red Deer Provincial Building, subsequent editions of design requirements have reduced the budget allowed designers to between 1000 MJ/m^2/year and 750 MJ/m^2 depending upon the size of the building.

TABLE 1

RED DEER PROVINCIAL BUILDING

ENERGY CONSUMPTION BREAKDOWN
(Including Parkade)

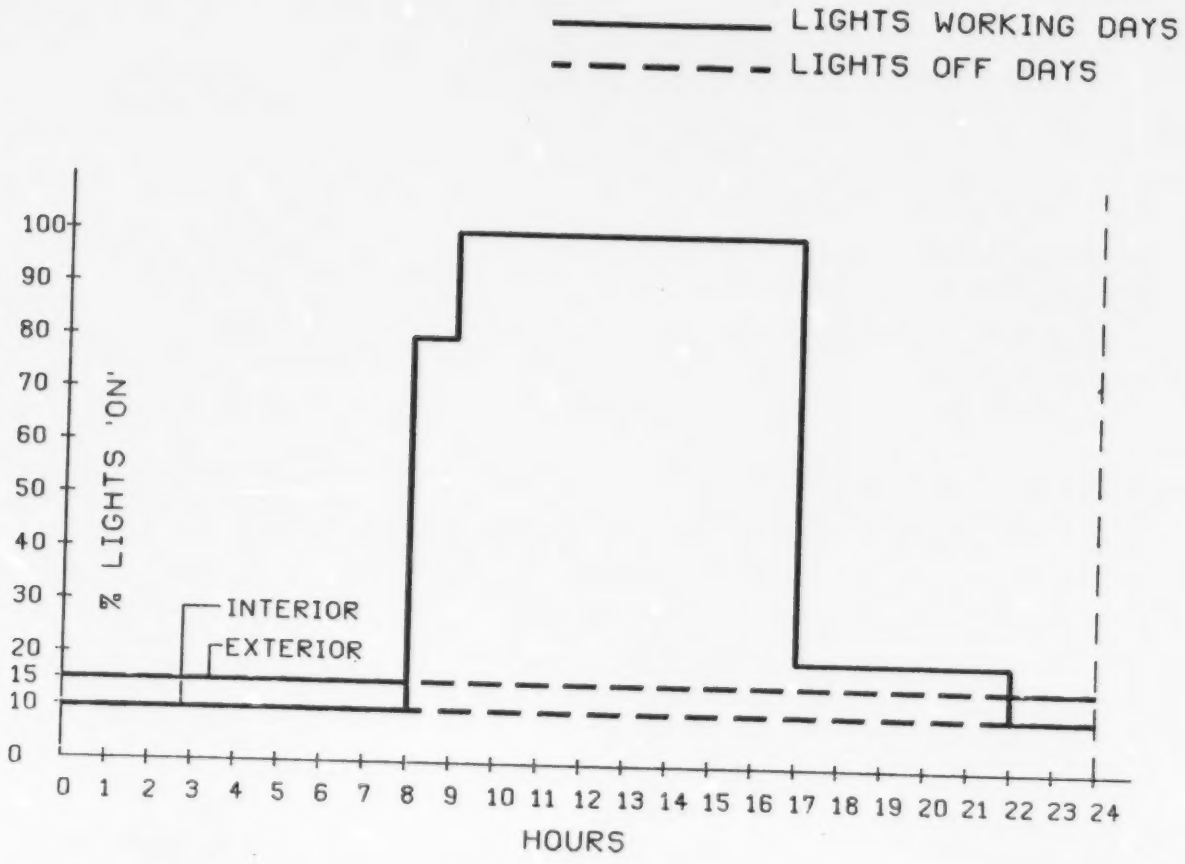
Load	Consumption (MJ)	Index MJ/m^2/year
Heating Consumption and Auxiliary Electrical Load	13,101,000	517
Direct Fired Heating Consumption	1,320,000	52
Cooling Consumption and Auxiliary Electrical Load	371,000	14.7
Lighting and Miscellaneous Power Consumption	5,740,000	226.7
Fans	573,000	26.6
Domestic Hot Water Consumption	458,000	18
Elevator Consumption	247,000	9.8
TOTAL	21,910,000	865

TABLE 2

ENERGY CONSUMPTION BREAKDOWN
(EXCLUDING PARKADE)

Load	Consumption (MJ)	Index MJ/m^2/year
Heating Consumption and Auxiliary Electrical Load	11,890,000	588.0
Cooling Consumption and Auxiliary Electrical Load	365,000	18.0
Lighting and Miscellaneous Power Consumption	5,342,000	264.0
Fans	389,000	19.2
Domestic Hot Water Consumption	458,000	22.6
Elevator Consumption	247,000	12.2
TOTAL	18,691,000	924

FIGURE 1

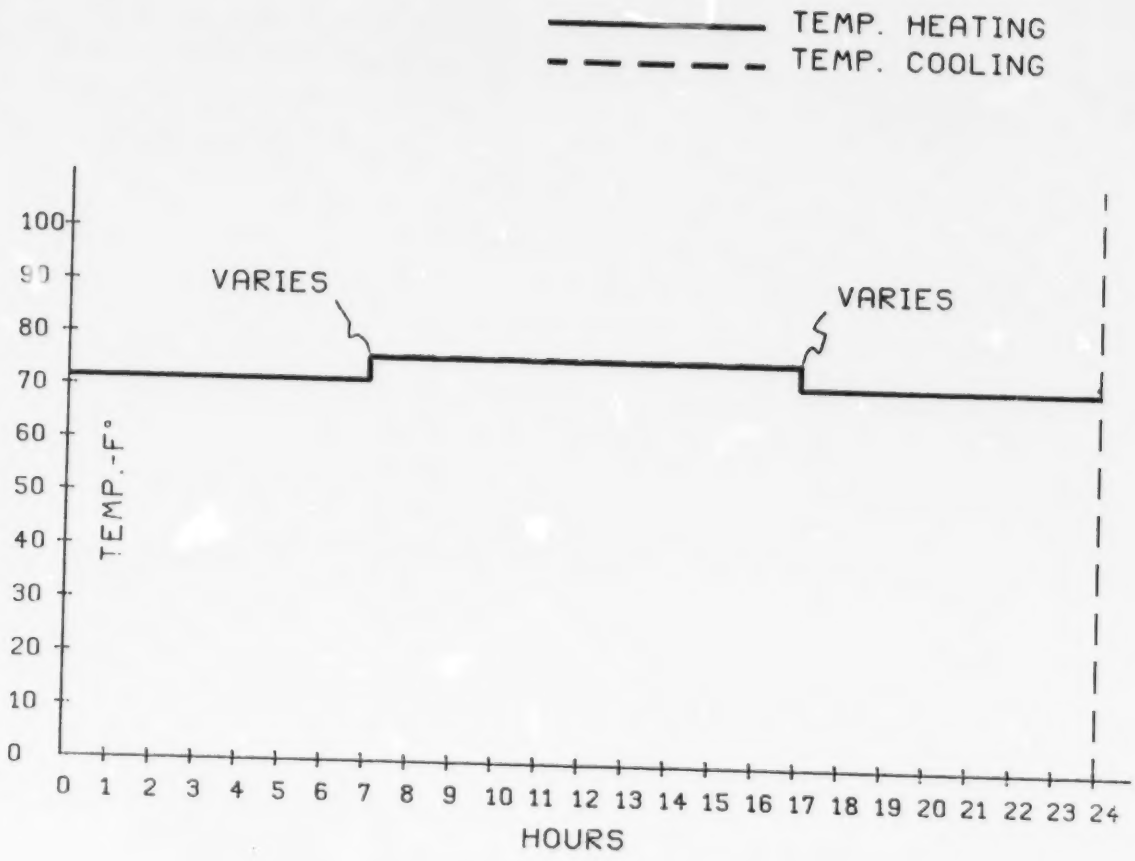


BUILDING LIGHTING PROFILE

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 2

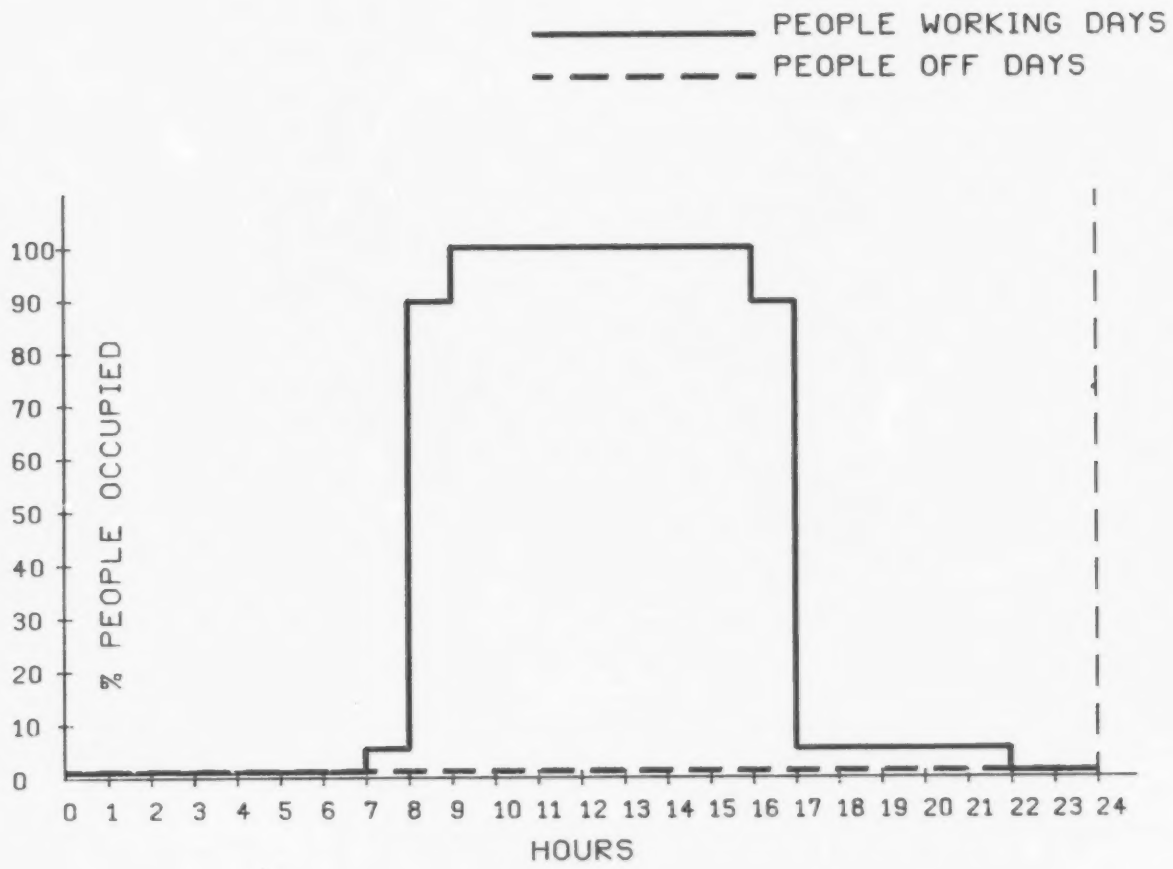


BUILDING TEMPERATURE PROFILE
HEATING & COOLING

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 3

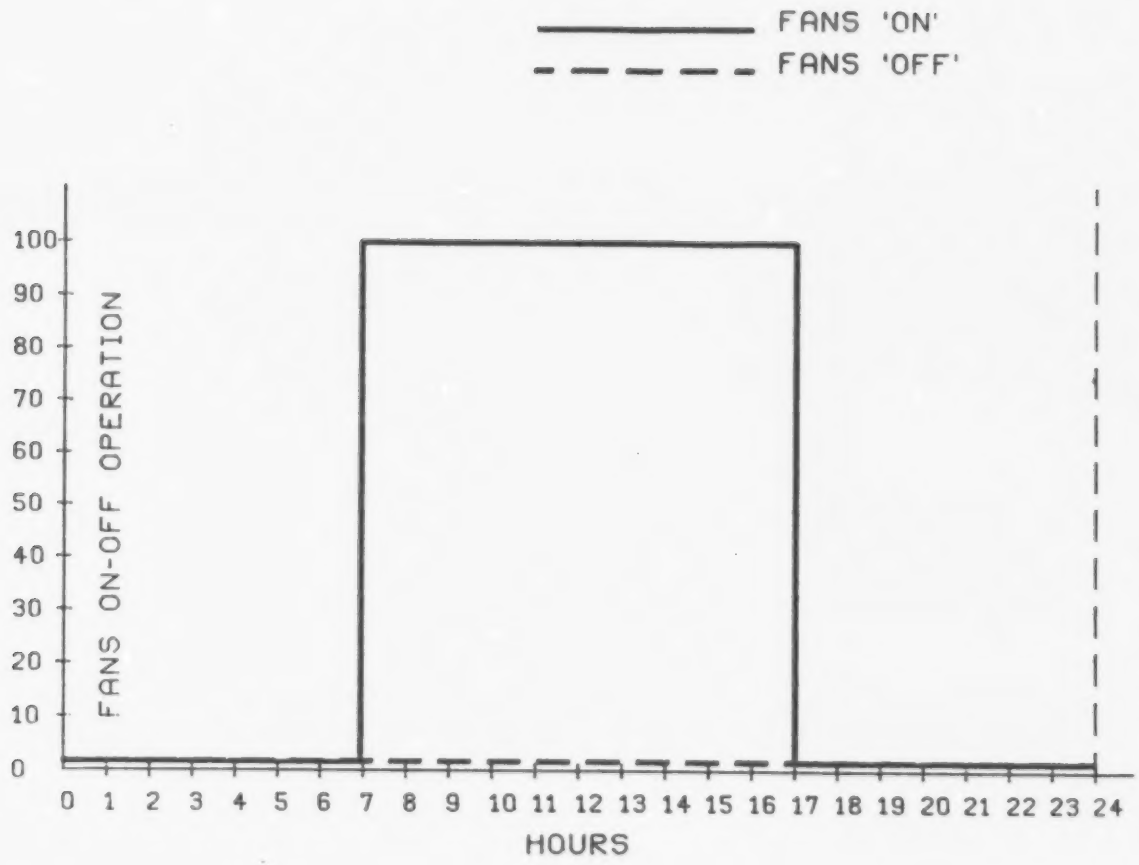


BUILDING OCCUPANCY PROFILE

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 4

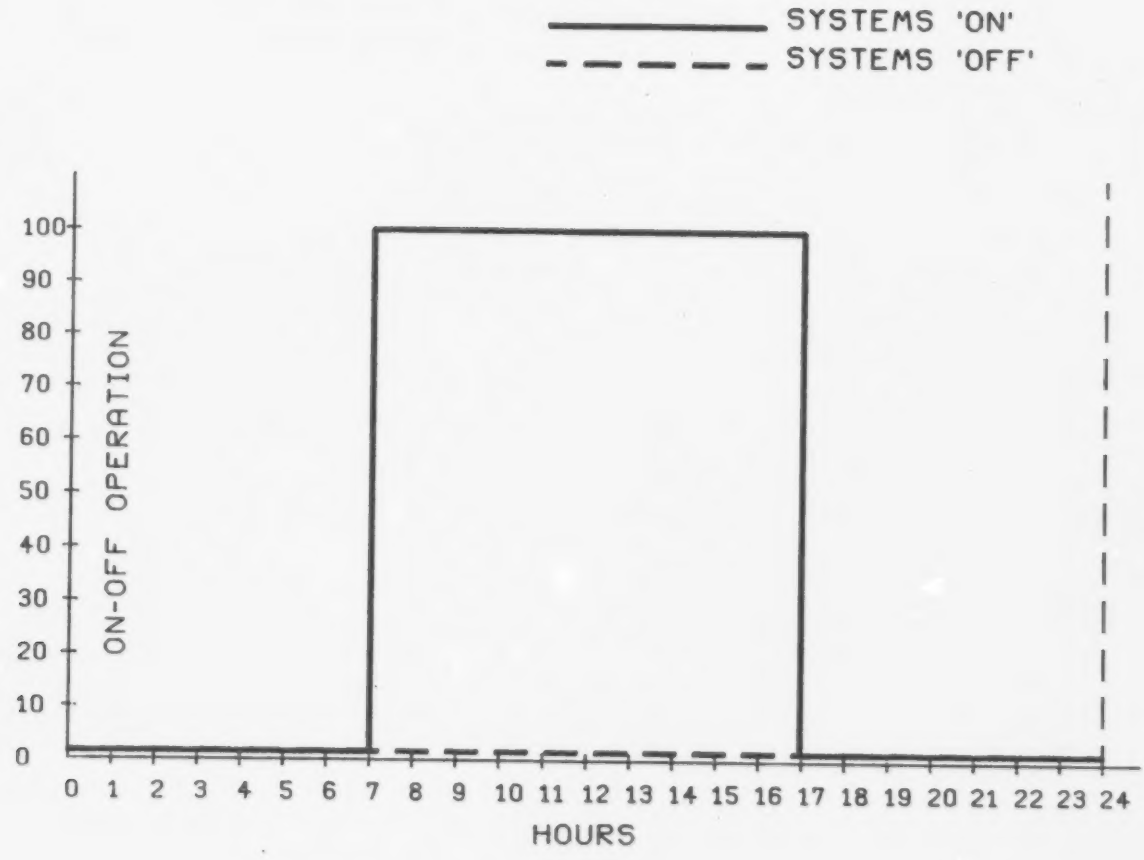


BUILDING VENTILATION & AIR CONDITIONING FANS OPERATION

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 5

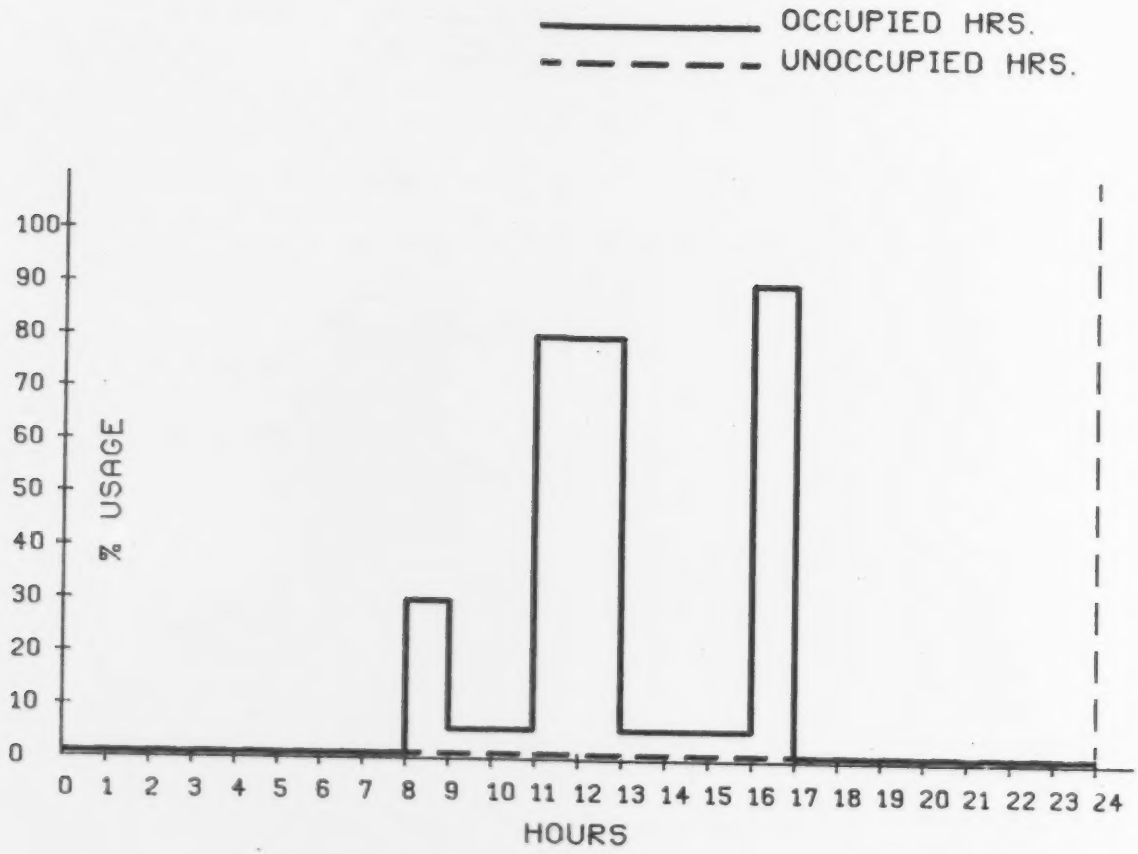


ON-OFF PROFILE FOR OUTSIDE AIR COOLING SYSTEM

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 6

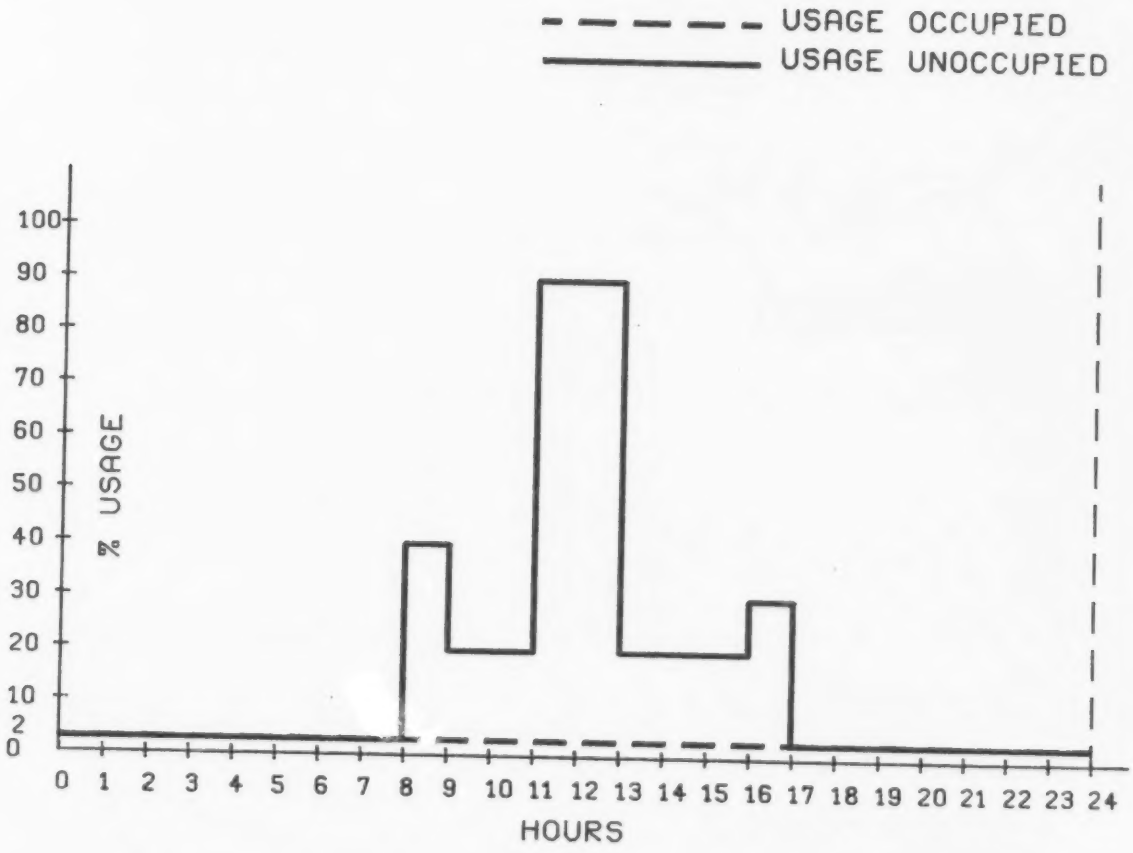


ELEVATOR'S USAGE PROFILE

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 7

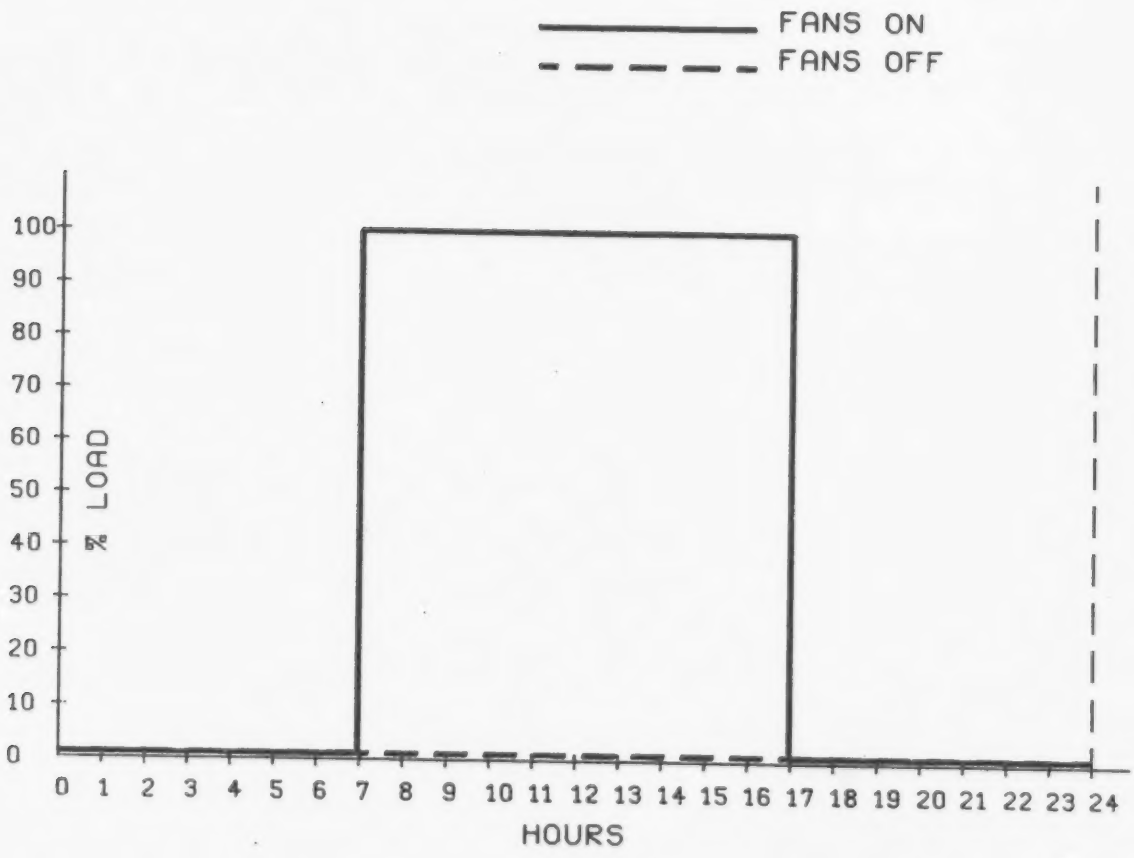


DOMESTIC HOT WATER USAGE

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 8

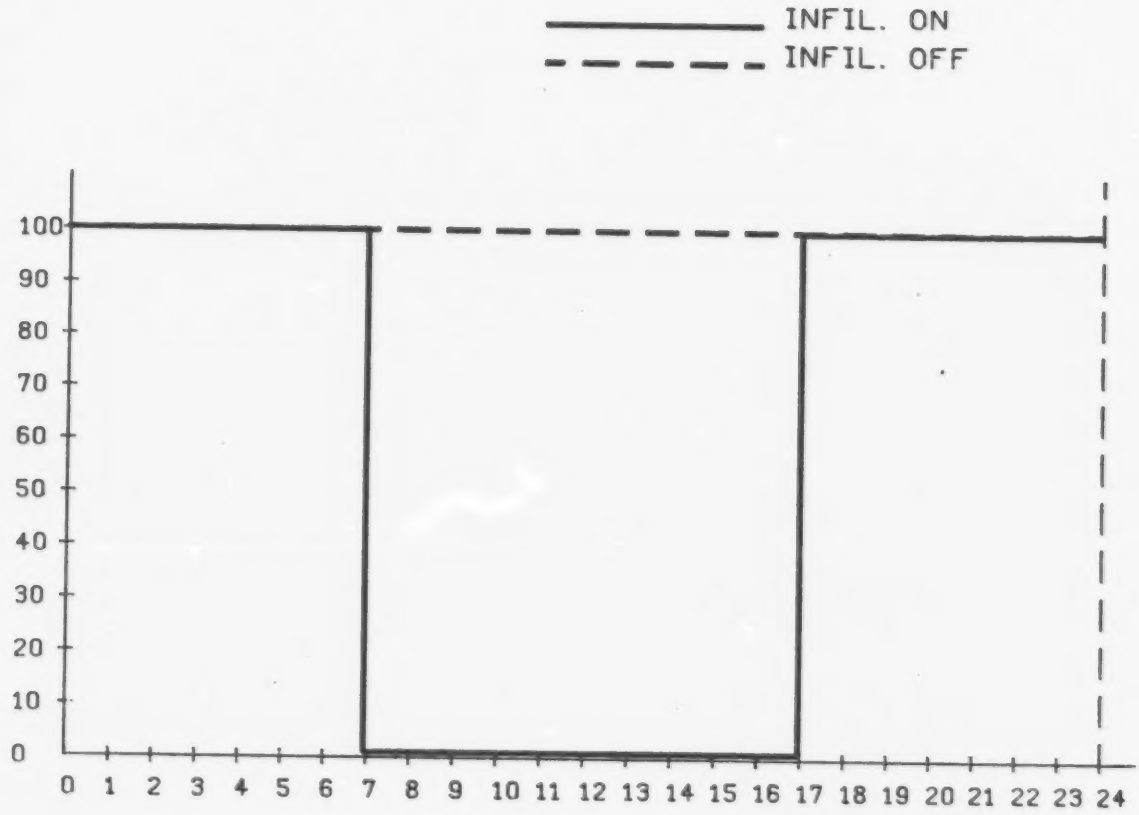


EXHAUST FANS OPERATING PROFILE

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 9



INFILTRATION

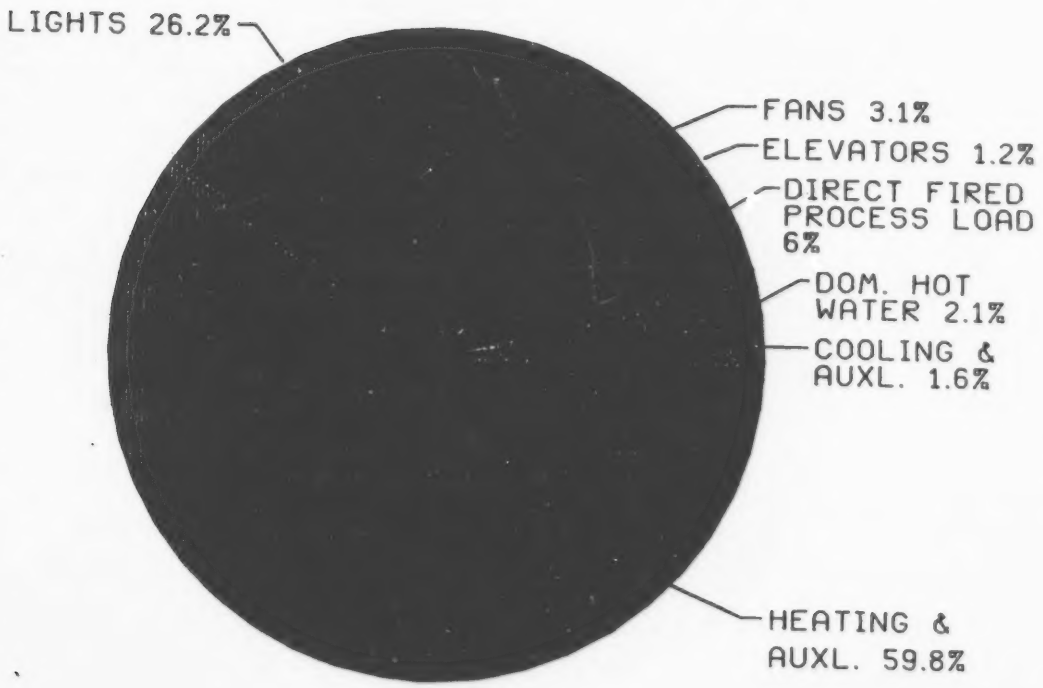
RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 10

ENERGY INDEX FOR BUILDING

865 MJ/M^2/YR. (INCLUDING PARKADE)



ENERGY USAGE CHART

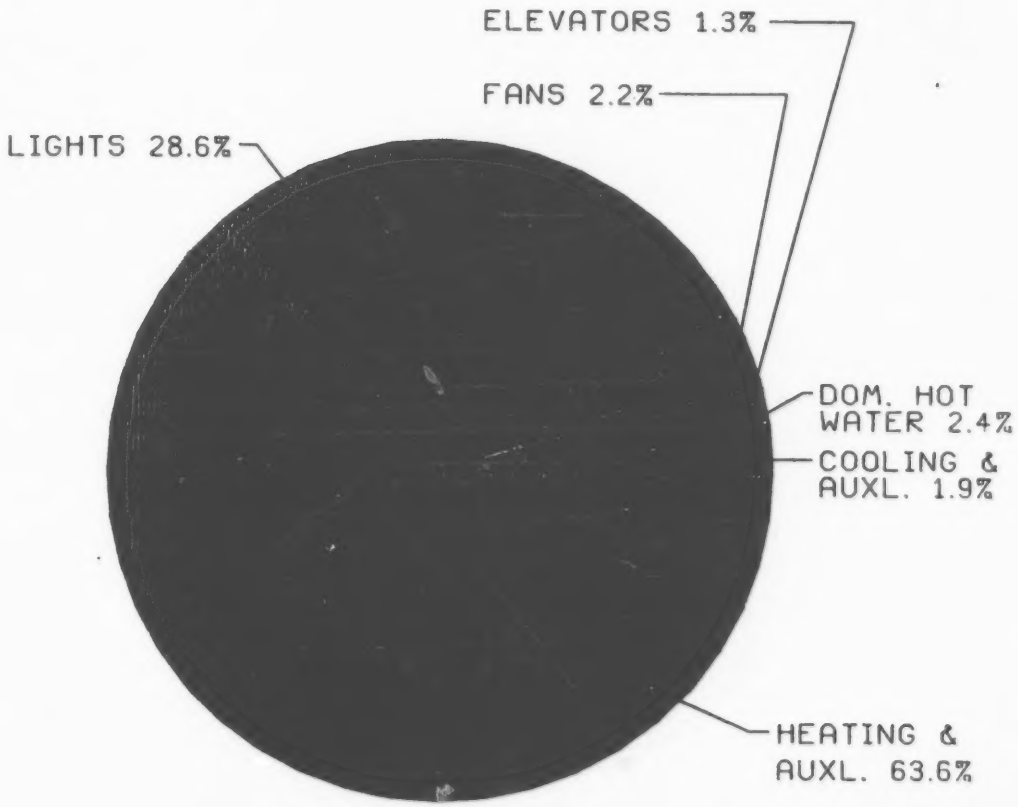
RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

FIGURE 11

ENERGY INDEX FOR BUILDING

924 MJ/M^2/YR. (EXCLUDING PARKADE)



ENERGY USAGE CHART

RED DEER PROVINCIAL BUILDING

CADD GRAPHICS

ENERGY-EFFICIENT OFFICE BUILDINGS
REPORT ON
THE PUBLIC WORKS CANADA BUILDING
LONDON, ONT.

by

Brian O'Donnell, P.Eng.
Engineering Interface Ltd.
Toronto, Ont.

Case Study

Public Works Canada Building

London, Ontario

INTRODUCTION

Annual energy performance of 756 MJ/sq.m./yr.(1981) qualifies the Public Works Canada Building in London, Ontario as being energy efficient.

Engineering Interface Limited of Willowdale, Ontario analysed the energy performance of this building for the National Research Council's project "Energy Efficient Office Buildings". Individual studies in selected office buildings were initiated to identify the reasons for good energy performance. The findings of these reports were then to act as an information transfer to designers of new office buildings to help them produce good energy results. They would also assist in selecting retrofit measures for existing buildings.

Built in 1976, the Government of Canada Building located at 451 Talbot Street is an eleven storey precast concrete structure with 19,963 sq. metres of office space. Architects were Tillman and Lamb; mechanical and electrical designs were by M.M. Dillon Ltd. (Subcontracted to Chorley and Bisset).

The original energy budget for the building calculated by the designers was 1150 MJ/sq.m./yr. Following several energy management retrofits in 1979 by Chorley and Bisset Ltd. annual energy performance has been:

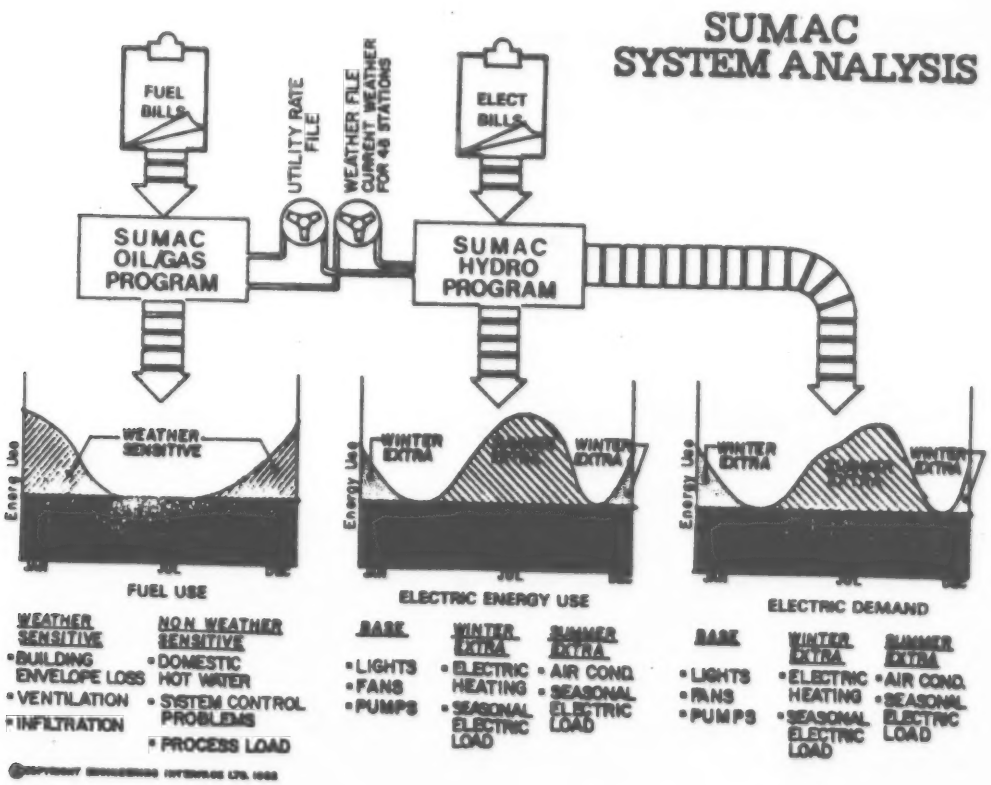
1980 - 751 MJ/sq.m./yr.
1981 - 756 MJ/sq.m./yr.
1982 - 809 MJ/sq.m./yr.

ENERGY ANALYSIS TOOLS

Two computer programs were used to analyse the building and its energy records to determine the reasons for energy efficiency.

SUMAC (System for Utility Monitoring, Analysis and Control) was used to evaluate the existing energy performance data. SUMAC separates energy use into eight components (see Figure 1 below). The program normalizes energy use for differences in weather and in billing periods. This allows direct comparison of different years of energy records for the same building or for similar buildings in different geographical locations. To date, over 2,500 buildings have been analysed by the SUMAC system.

Figure 2 shows the energy use for this building, and for the average of 85 other PWC buildings, split into the 8 SUMAC energy use components.



SUMAC ENERGY COMPONENTS

FIGURE 1

BUILDING ENERGY AUDIT

Figure 2

SUMAC

BUILDING: 451 TALBOT-MERIWETHER/SUMAC (WITHOUT GARAGE)

ENERGY PERFORMANCE (MJ/SQ.M/YR)

PERIOD	FUEL: NON-WEATHER SENSITIVE	FUEL: WEATHER SENSITIVE	FUEL: TOT	ELECTRICITY: BASE	ELECTRICITY: WNTR EXTRA	ELECTRICITY: SMMR EXTRA	ELECTRICITY: TOT	***** GRAND TOTAL
MERIWETHER	30	293	323	380	10	33	443	766
01/80-12/80	17	290	307	382	14	48	444	751
01/81-12/81	25	296	321	391	12	32	435	756
01/82-12/82	26	293	319	448	10	32	490	809
AVERAGE FOR THIS TYPE OF BUILDING	178	678	856	383	34	54	472	1329

DEMAND PERFORMANCE (J/S/SQ.M.)

PERIOD	DMD	BILLING DEMAND: BASE (HRS/WK)	BILLING DEMAND: WNTR EXTRA	BILLING DEMAND: SMMR EXTRA	BILLING DEMAND: TOT
MERIWETHER	37.8	(57)	0.1	10.2	48.1
01/80-12/80	38.1	(54)	2.2	7.3	47.6
01/81-12/81	38.1	(55)	1.8	5.5	45.4
01/82-12/82	38.1	(62)	2.9	5.2	46.2
AVERAGE FOR THIS TYPE OF BUILDING	26.9	(76)	1.6	5.0	33.5

+++WEATHER SENSITIVE COMPONENT NORMALIZED TO WEATHER CONDITIONS OF STANDARD YEAR IN LONDON

SUMAC was useful in the building analysis to:

1. establish in detail the actual energy performance of the building over the three years audited.
2. track eacn component of energy use over the three years to establish trends or consistency in performance.
3. compare each component of energy use with the SUMAC database of 85 Public Works Canada office buildings to identify components showing better than average performance.
4. verify the model obtained by Meriwether simulation.

The Meriwether Energy Systems Analysis Program was used to calculate building energy use by simulating the building, its energy using systems and their operating periods. Using these parameters, it calculates hour by hour energy requirements.

The Meriwether simulation was used in the building analysis to:

1. establish the theoretical energy requirement of the building based on its architecture and on system design and operation.
2. establish the theoretical energy requirement of individual building systems.
3. establish the impact of changes in system design or operation.

Because of the sophistication of the Meriwether program and the number of input variables it was considered important to verify the accuracy of the simulation. In 1976 the National Research Council conducted a study on the use of Meriwether by 25 of the most frequent Canadian users of the program. Each was given the same building to simulate. Figure 3 shows plots of the simulated fuel and electricity requirements for the building as computed by the 25 practitioners. Results show a maximum variance in predicted fuel use of 105 percent from average.

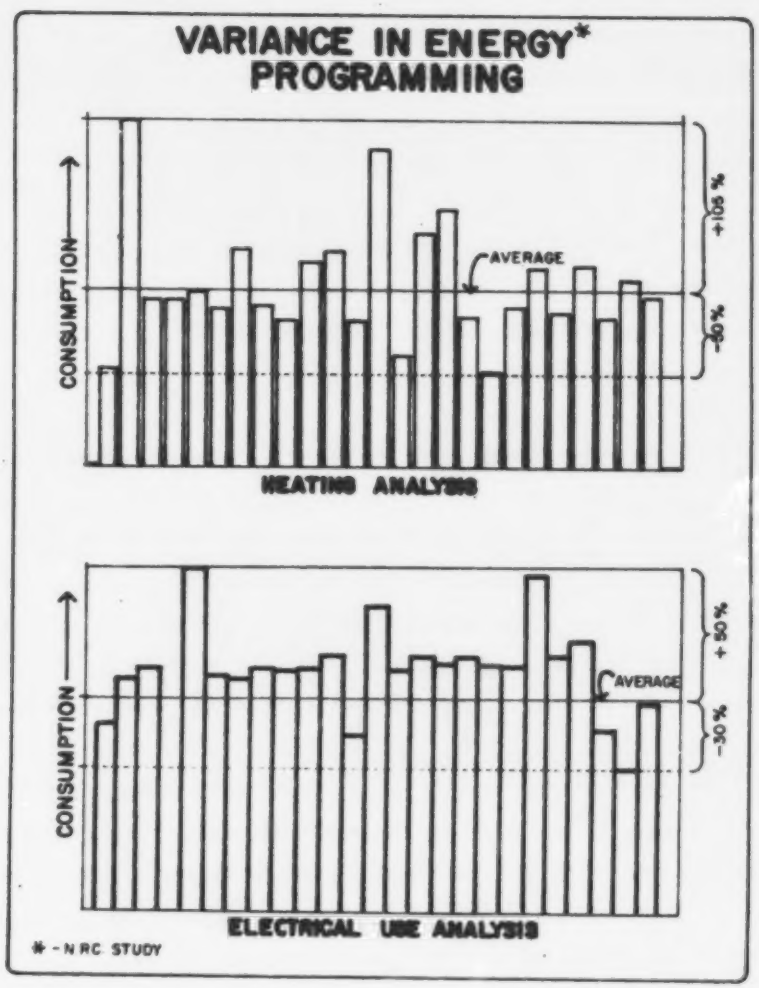


FIGURE 3

The lower graph, showing the simulated electricity use, has better correlation with only 50% maximum variance from average.

Fortunately, in simulating an existing building, the analyst can compare his results to actual historical utility data.

SUMAC extends this comparison beyond total energy use. Meriwether output of monthly energy use can be analysed by the SUMAC program. Figure 4 shows an example of Meriwether simulated fuel use compared to actual fuel use based on weather (degree days). The upward sloping lines indicate the increase in fuel use as the outside air temperature decreases.

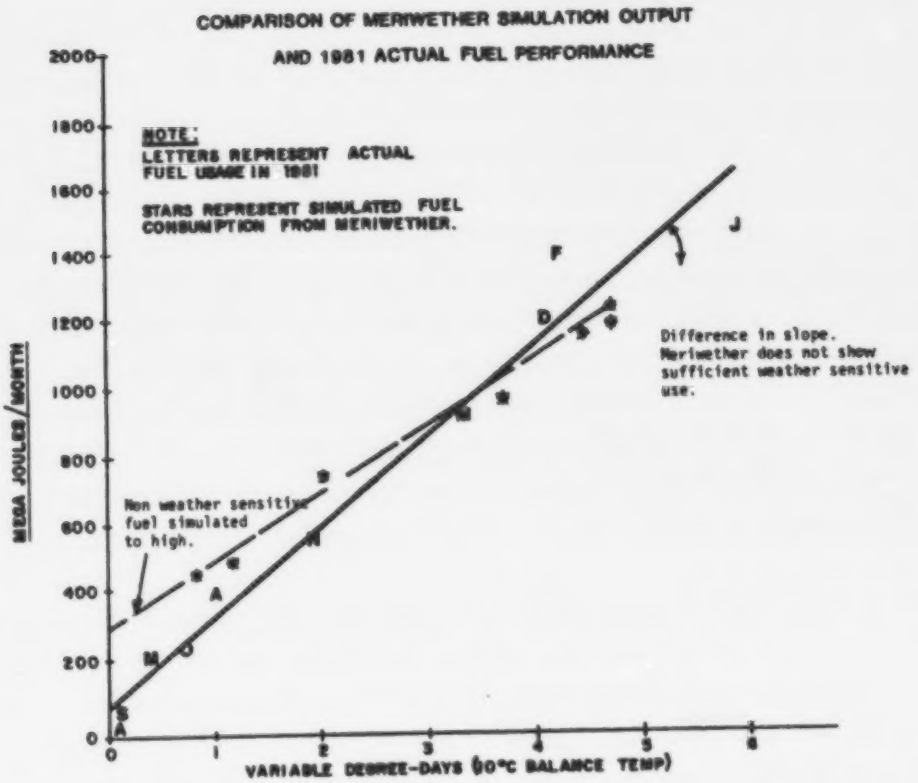


FIGURE 4

Although total actual fuel use and simulated use only varied by one percent, the graph shows the simulation was not perfect in modelling actual fuel performance. By adjusting simulation input and recomparing results to actual performance "perfect" simulation can be verified.

BUILDING PERFORMANCE

The SUMAC analysis revealed better than average energy performance in the following areas:

fuel use not related to weather	- 85 percent below the P.W.C. average
fuel use related to weather	- 54 percent below the P.W.C. average
Winter extra electricity use	- 70 percent below the P.W.C. average
Summer extra electricity use	- 40 percent below the P.W.C. average

FUEL - ENERGY EFFICIENT FEATURES

1. Variable Air Volume Air Conditioning

Air conditioning reheat, a major contributor to non-weather sensitive fuel use in many commercial buildings, is almost nonexistent here. The building uses variable air volume compartment air handling systems which vary the air flow according to the space requirement. Perimeter reheat, usually found in VAV systems, has been minimized by reducing the minimum air flow to the perimeter areas. Fuel savings relative to the "average" PWC building and attributed to use of this type of system are estimated at $40,000 annually.

2. Purchased Steam

Heating the building using purchased steam avoids boiler conversion losses of 20-50 percent. Other advantages include reduced capital and maintenance costs, simplicity of the system, as well as saving the salary of a stationary engineer. The main disadvantages of purchasing steam are the price (over 2 times that of natural gas in London), and being "locked into" a sole supplier.

The energy savings compared with the PWC average due to use of steam rather than a building boiler amount to 125 MJ/sq.m./yr.; however, because of the high price for steam, there is an annual energy cost premium of $34,000.

3. Operation

Weather related fuel use is also reduced by controlling fan operating hours and by setting back the scheduled temperature of the perimeter radiation.

Fan operation is controlled by mechanical timeclocks. The ventilation fan operates 50 hours per week; the compartment (VAV) fans operate 60 hours per week.

If overtime fan operation is required, only the fan on the occupied floor is activated. This gives a great advantage over more typical buildings where the entire building is conditioned by a single fan system.

Setting back the temperature of the perimeter radiation on nights and weekends prevents overheating rather than reducing the space temperature. This is because the radiation is sized to overcome both transmission losses and overcooling by minimum airflow through the perimeter VAV diffusers.

Savings for these operating procedures are estimated to be 137 MJ/Sq.m./yr. worth $35,000.

4. Improved Building Envelope

Heat loss through the building envelope has been lowered by reducing the window area and by tightening the building envelope against air infiltration. Air infiltration is estimated to be 50-75 percent lower than the average building. Glazing makes up approximately 25 percent of the wall area rather than the more typical 35-75 percent. This reduces transmission heat loss, solar heat gain and the amount of window perimeter subject to infiltration.

Infiltration is further reduced by using a double layer of gyproc extending from slab to slab.

These measures are estimated to save 178 MJ/sq.m./yr. compared to the PWC average use worth $47,000.

ELECTRICITY - ENERGY EFFICIENT FEATURES

The nature of the building systems causes a higher than average electrical load. Electrical demand is approximately 40 percent higher than the PWC average. However, electricity consumption for lights, fans and other loads used all year is only slightly higher than the PWC average.

1. Operation

Electricity consumption, compared to demand, is low due to much shorter operating hours of electrical systems. Rigorous manual control of the lighting systems and timeclock control of fans are estimated to save 145 MJ/sq.m./yr worth $13,000 annually.

2. Delamping

The building lighting load has been reduced from 34 to 24 Watts/sq.m. by disconnecting selected lamps and ballasts. Light levels were lowered from 100 footcandles (1100 lux) to task levels as prescribed by Public Works Canada.

Delamping of 200 kW of lighting load saves 10 MJ/sq.m./yr. worth $7,000.

3. Free Cooling Cycle

The compartment VAV system requires cooling for the interior system year round. The amount of ventilation air supplied to the building is fixed. Cooling must therefore be provided by chilled water supplied to the compartment units. This chilled water requirement would normally require chiller operation all year. However, the chiller has a "free cooling" cycle allowing water to be chilled in

the winter using the cooling tower instead of the compressor. Free cooling is available whenever the outside air temperature is less than 7°C (45°F).

The free cooling cycle is estimated to save 6 MJ/sq.m./yr. worth $2,000.

Electrical energy use for cooling during the summer is considered to be energy efficient compared to the PWC average use because of:

- reduced reheat using VAV air conditioning
- reduced cooling load for lighting load and shorter hours of lighting operation
- reduced solar gains due to the lower glazed wall area.

Savings in summer energy are estimated at 30 MJ/sq.m./yr. worth $8,000.

SUMMATION

The Savings Summary, Table 1, shows that the main reasons for energy efficient operation are the building systems and their operation.

Building systems in this case are demand sensitive and demonstrate simplicity in design and control.

The cost savings indicate the important role of the building operator in achieving energy efficient operation.

The key recommendation to building designers is to involve the operators early in the design of a building to ensure system operation and control are understood. An energy conscious building operator is the key ingredient to energy efficient building operation.

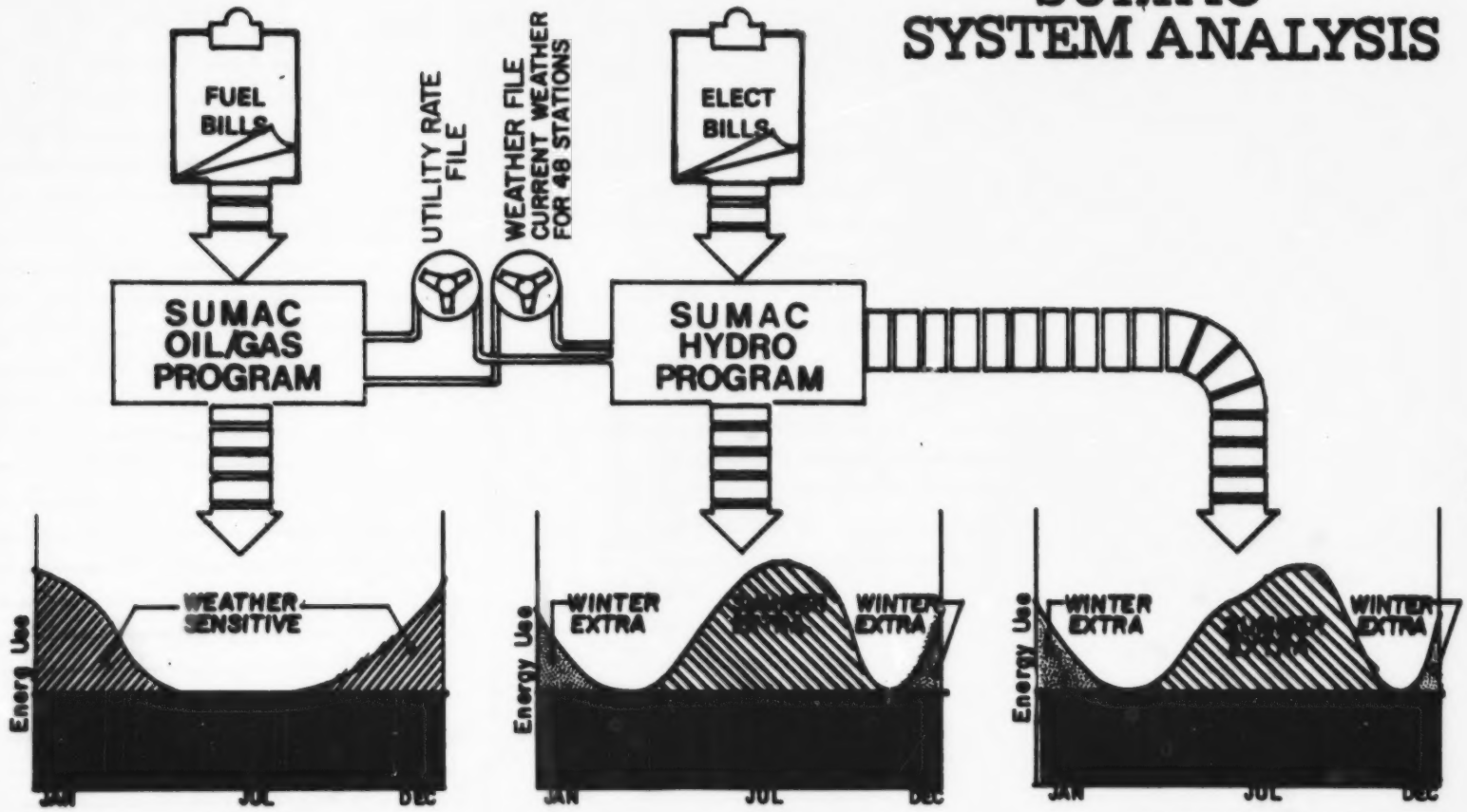
TABLE 1

SAVINGS SUMMARY

This table summarizes the energy efficient features found at Government of Canada Building, London. Savings are predicted based on what the building would have used according to the Public Works average.

Systems	MJ/sq.m./yr.	$/sq.m./yr.
1. Variable air volume compartment air conditioning systems		
savings in fuel use (reheat)	150	2.0
savings in electricity use for cooling	18	0.09
2. Purchased steam instead of self generated savings in fuel use	125	-1.75
3. Free cooling cycle on chiller savings in electricity use for cooling	3	0.10
4. Delamping	10	0.09
Sub total	306	.53
Architectural		
1. Reduced glazing area		
savings in fuel use for heating	115	0.15
savings in electricity use for cooling	2	0.02
2. Tight wall construction savings in fuel use for heating	63	0.84
Sub total	180	2.36
Operational		
1. Short operating hours for lighting, fans, pumps		
savings in base electricity use	145	1.21
savings in fuel use for heating	63	0.84
savings in winter extra electricity	23	0.19
savings in summer extra electricity	17	0.14
2. Night setback of heating water reset schedule	93	1.15
Sub total	341	3.53
TOTAL	827	6.33
Remaining energy use	809	9.51

SUMAC SYSTEM ANALYSIS



WEATHER SENSITIVE	NON WEATHER SENSITIVE
• BUILDING ENVELOPE LOSS	• DOMESTIC HOT WATER
• VENTILATION	• SYSTEM CONTROL PROBLEMS
• INFILTRATION	• PROCESS LOAD

BASE	WINTER EXTRA	SUMMER EXTRA
• LIGHTS	• ELECTRIC HEATING	• AIR COND.
• FANS	• SEASONAL ELECTRIC LOAD	• SEASONAL ELECTRIC LOAD
• PUMPS		

BASE	WINTER EXTRA	SUMMER EXTRA
• LIGHTS	• ELECTRIC HEATING	• AIR COND.
• FANS	• SEASONAL ELECTRIC LOAD	• SEASONAL ELECTRIC LOAD
• PUMPS		

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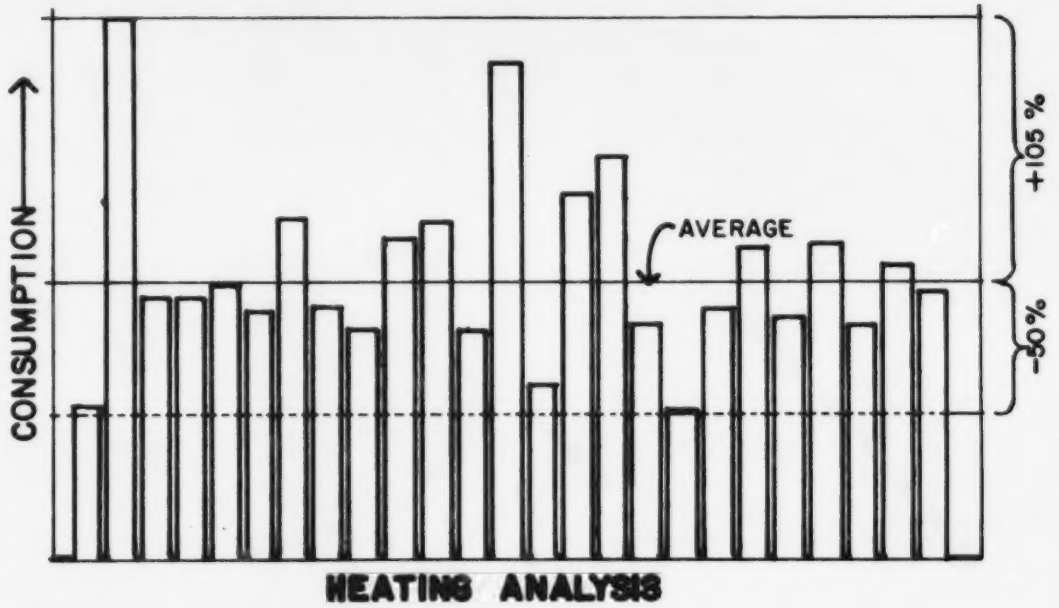
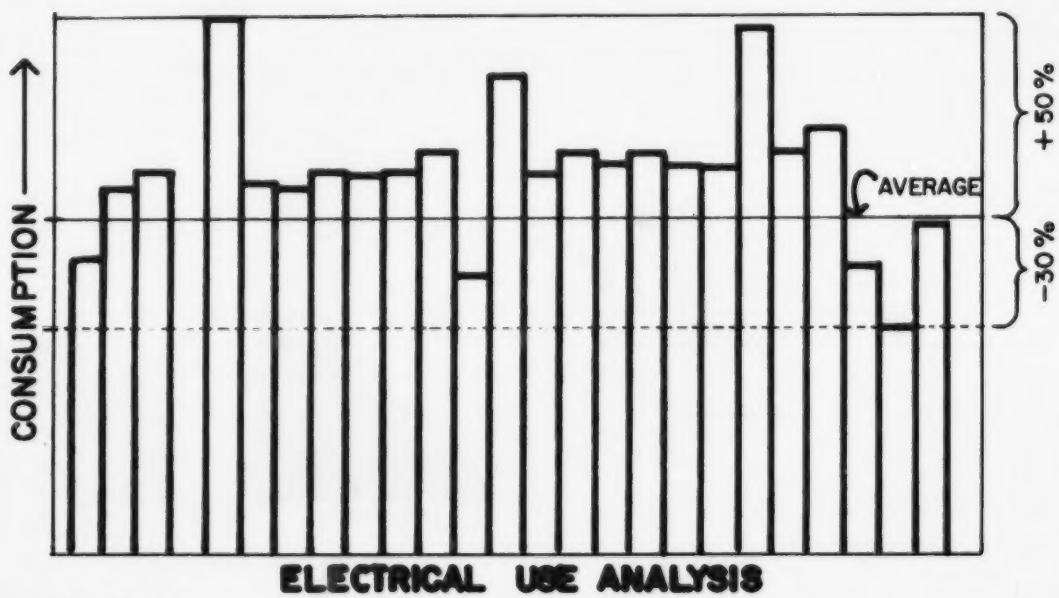
VARIANCE IN ENERGY* PROGRAMMING



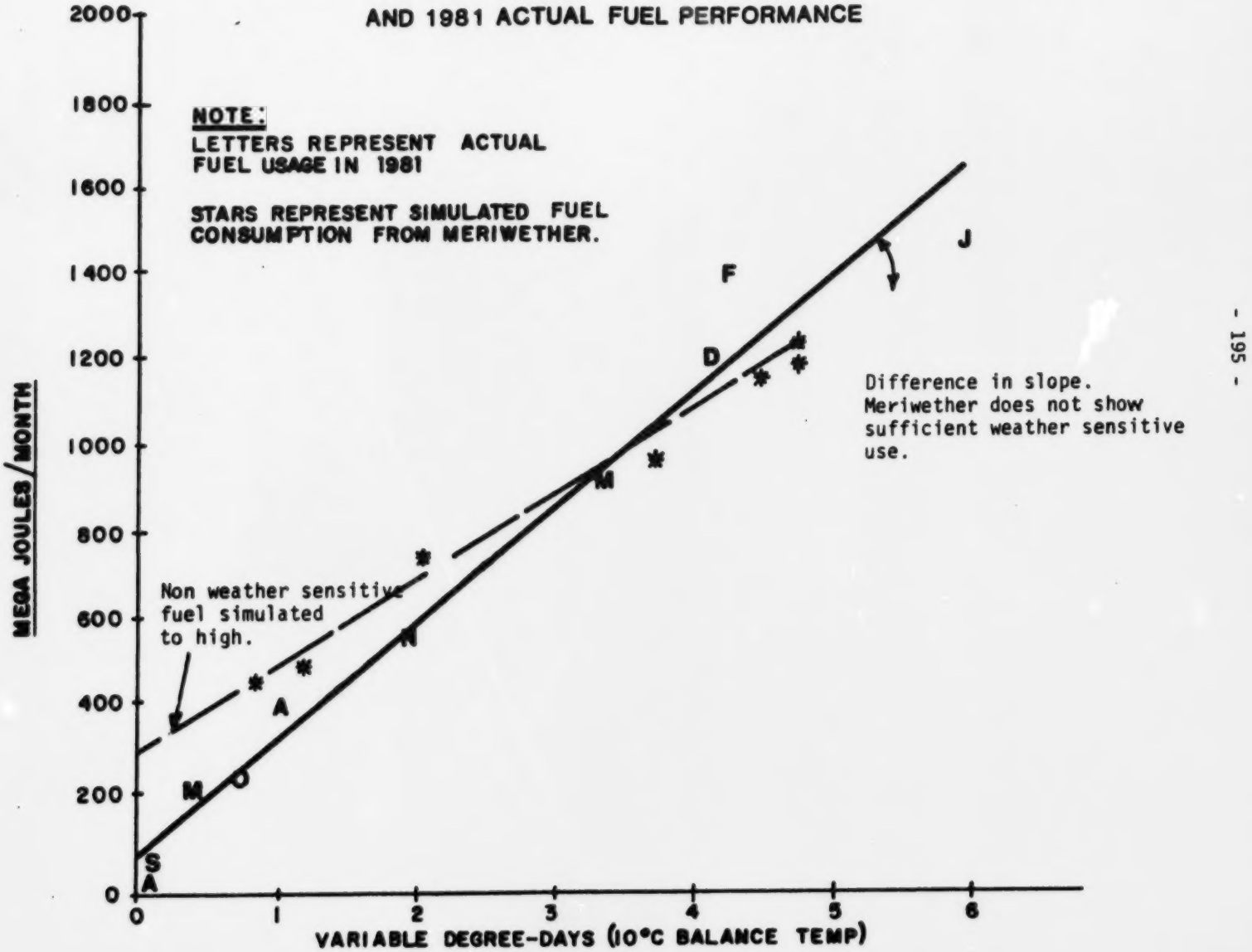
HEATING ANALYSIS



ELECTRICAL USE ANALYSIS

* - N.R.C. STUDY

COMPARISON OF MERIWETHER SIMULATION OUTPUT AND 1981 ACTUAL FUEL PERFORMANCE



SUMMARY OF THE GENERAL DISCUSSION

and

COMMENTS ON THE RAPPORTEUR'S PRESENTATION

Editor's Note: The questions and answers included in this section were transcribed from a tape of the discussion held at the conclusion of the symposium. They therefore reflect the spontaneous nature of the discussion and although we have done some editing, we have not been able, for obvious reasons, to cast all of the information into formal prose. Indeed in some cases we have not been able to interpret the speaker's exact meaning but we have nevertheless included such information in the hope that readers may find some "wheat in the chaff".

B. Denchors

Could you define what you mean by "resource energy"?

H. Elmahdy, National Research Council

In the report, the authors could not give any definition of resource energy, but I think what they meant is that they have taken into consideration the cost of conversion. So if you use oil you have to account for combustion losses and also the cost of transportation and so on.

S. Dubash, Public Works Canada

There is also the cost of getting the fuel out the ground and the cost of transporting it. In other words, it would cost you one quarter pound of coal to get one pound out of the mine and another quarter pound to transport it. Then essentially your resources have multiplied and will be added to your conversion at the plant within the building. So you are using one pound but you actually use one and one half pounds at the mine.

R. Biggs, National Research Council

What is the resource energy associated with electricity generated from hydro power or nuclear? This is a debate I have heard a number of times and have never seen a resolution to it. It is a complex issue as to what is the right number.

F. Vaculik, Public Works Canada

We had to face this issue because a lot of Public Works buildings had in-house boilers and some had central heating plants. We wanted to compare apples with apples. So we have to face the issue and somehow see where we stand in an evaluation of performance. If you are the owner of a building that has everything in it, then you take this point of view. If you are the owner of a campus with a central heating plant, then you are purchasing oil, or gas or hydro, and you take it from that point of view. If you do it for EMR, you take it from the national point of view. I would say from the global point of view that you would even include the transportation costs for the oil from across the globe. If we want to compare buildings we have to choose from what point of view we are comparing them and whatever the figures used for consumption we should be able to translate from one point of view to the other. That is probably the only practical approach.

F. Berry, Public Works Canada

The direction we are taking right now in assessing our buildings is targets and budgets. We've gone to site energy. There have been studies on some of our simple heating plants to find out what distribution losses we were getting and it is very interesting to hear about the building in London because someone has to pay for those distribution losses. Do you charge them against the building or do you charge them against the central heating plant? So, what we have decided is the point of entry, and that point of entry is where the target is taken from. We don't quote the distribution losses on the building. We assess it back to a plant. But that reflects of course in the cost of energy sold to the building. To go back to the

argument, is it fair to compare a building served by a central plant with one that has its own autonomous plant? That comes out from the life cycle costing. Because at that stage you've got capital costs and operating costs which come out to a total life cycle costing. So it does bounce out in that respect. Now we had a case in Ottawa, I think at Tunney's Pasture, where the distribution losses were about 5 or 6%, which is unreal. But in downtown Ottawa, they are something like 15 to 20%. And that has been charged against the plant, not against the Parliament Buildings. Another thing I wanted to get to was about the abnormality of so-called Canadian buildings looking very efficient. I have been through some buildings from 1970 and I could have given you 20 straight off the bat that were under 800 megajoules per square metre. With that graph you put on there I could swing a lot to the left and maybe in an inventory of 6000 buildings we can show you the complete spectrum from 400 up to 4000. I have another difficulty with the term office building. It has to be defined because you get offices that have got a base load of computers which you can't get rid of or do anything about. And then you have buildings like those at Tunney's Pasture that are research oriented. So you have a complete range of buildings from straightforward, sit-down-and-turn-on-the-lights types to buildings that have exhaust hoods because they're dealing with carcinogenic materials. Therefore I would say that you have to break down office buildings a bit more. You've got to break them down into two-shift type operations and single-shift.

It's so difficult to quote 10 consultants in, give them very fixed guidelines and get the 10 to be exactly what you want. So we started to formulate our own targets. I like the way Frank wants to go. I've seen it before. It's not an original idea but at least he is pushing it. It's to go in terms of budgets. We kind of eliminated a rather expensive up-front cost to come out with a budget for our buildings, whether they be existing or new. Our design people have just been putting a finger on this. Say 600 was a good number for a new building a few years ago, but we have no real hope that 600 was the best number. You know that with any computer program, if you want 600 the computer will give you 600. But 400 or 300 may have been a much better number. It is somewhat like what Ross Merriweather once said, "what number do you want"?

B. Scally, Public Works Canada

One thing that was mentioned casually and that we really didn't have time to get into was the fact that in too many of our buildings I think we are generating steam which we then convert straight back to hot water to use and with a double set of losses and some inefficiencies in the steam generation that could be eliminated by generating directly in hot water in the first place. A second point was, again if we go back to the actual cost, in 1977 I had an occasion to do a study on a building in London. It's very close to the one you are talking about and it was on the same steam system. When the results came out, it just jumped out at you that the best way to save money, about 70% of your cost, was to get off that steam system. Now the cost of that system is a pretty good indication because it's a commercial one, not a government one where they can put artificial figures on the cost of steam. Those guys who are running it to sell steam to try to keep the operation going. So the price of that steam gives you a pretty good idea of what the cost of the energy is.

R. Monteyne, Vinto Engineering

It is important for comparison to know the basis for normalization. What is a square metre? Is it a gross square metre? A net square metre? Or a net usable square metre? Because if it is the same as Bell Canada, they include the area of their parcade and their net gross area of the building and divided by the energy consumption they get down to 500 or 450.

H. Elmahdy, National Research Council

The original paper did not specify the definition of the area used in normalizing the energy consumption. But what I am trying to say here is that we are having difficulties in defining the basis for comparison and the definition of important parameters such as "efficient building", "resource energy", and the "space area" used in the normalization.

C. Roy, CRS

I would like to add a few comments. Presently in Quebec, electricity is cheap. There is also natural gas coming into Quebec from the West. People are not buying natural gas. Why? Because first of all the cost of natural gas is mainly capital cost to put a pipe in the soil, and natural gas companies try to get fixed contracts from their clients. And with the current price of oil, people are not buying natural gas. The same thing with electricity. Since the Bay James project has been completed, conservation efforts have cut down demand in Quebec and now Quebec has a surplus of electricity. So we got natural gas at a cheap price. We got electricity at the cheapest price and we could get bunker C oil in Quebec at a cheapest price. I remember four years ago one of my clients had a large bunker C heating plant recommended to take it out and bring in natural gas. Four years ago there was a surplus of bunker C oil and we were planning this year that there was not going to be any bunker surplus but there still is so this guy is made at me. The point I am trying to get at is that we have to be very cautious about the source of energy. We also have to provide for future years. Electricity, when it is in a stable demand, is a good choice. Natural gas is also a good choice when there is a stable demand. But, in wintertime, what I think would be a wise choice for a building operator is to have heating plants joining energy from all three sources. Natural gas boiler, bunker C boiler and electric boiler, and that's what I'm trying to sell my clients right now. Use electricity. We are putting 25- and 50-megawatt boilers right now in Quebec out of electricity. Can you imagine the size of these 50-megawatt boilers? Directly connected to a 25-kW line? The dam will be running that boiler by itself. So as mechanical engineers I think we have to be very careful about these recommendations.

D. Stephenson, National Research Council

Just a minor point on the interpretation of some of the buildings that were shown on that composite graph. I noticed that you showed some European and some Swedish buildings and I think it's worth questioning how the resource energy was computed in the case of those European buildings. Some of them, I'm almost certain, would have used by-product heat from a combined heat/power plant, and I suspect that there the factor is less than or not more than one because it is heat that has already been written off in terms of generating electricity in part. And yet it is still at its low grade, it

is still used for space heating by their district heating networks where there is a combined heat/power type of plant and the source for district heating, and I suspect that those Swedish numbers are lower on that account or at least some of them are.

R. Biggs, National Research Council

Don, could you comment on a Monsieur Roy comment that one needs some diversity, which reminded me of the message you brought back from Sweden on their rationale for the type of energy system they have adopted nationally, which would seem to me to have somewhat the same sort of basis.

D. Stephenson, National Research Council

The Swedes have set themselves really on an unusual problem like Canada. They have, at the moment, a surplus of electricity. They've got nuclear plants that are under construction and their program, their policy, is to complete the nuclear plants now under construction to use the electricity they produce while those plants have a useful life, but not to replace them with further nuclear plants. So they've got a situation where they need to use electricity over about the next fifteen-year span and then they need to have an energy system that will not be committed to nuclear power. What they are doing to get around this, to use the electricity now and avoid being addicted to it, coupled with the fact that they've got large heating systems, is going to heat pumps, electrically driven heat pumps supplying the district heating systems. They'll use power from the nuclear generating plants to drive these heat pumps until the second half of the next decade, between 1995 and 2000. At that point, as they start to decommission their nuclear plants, those big heat pump district heating systems will be converted to combined heat and power and so they continue to supply heat into the district heating network but instead of drawing electricity from the general grid to drive an electric heat pump, the combined heat/power plant will be feeding electricity back into the grid to replace part of the energy that previously came from the nuclear system. This strategy seems to make sense if you set yourself this difficult problem of using electricity for a while but not getting addicted to it, and this is how the Swedes are tackling it. And it is possible in their case because there is already a fairly extensive system of district heating using hot water.

E. Sherman, Public Works Canada

One of the things I find interesting about the Owens Corning studies -- I'm not familiar with all the buildings though I am with some of the ones that have won awards -- is that they have a different approach. I think we have been saying that most of the buildings we have seen over the last two days would be termed non-weather-sensitive. The winners of the Owens Corning competition, I think the designers of those buildings look upon them as rather weather-sensitive and it would be very rare for instance to see things like the building treated the same on all four facades which we have seen in the buildings today. They also stress the strategies like daylight, night flushing for instance to take advantage of cool evenings and a lot of the climates and warm days. Passive solar is sometimes taken to extremes in a lot of those buildings. They use off-peak power to generate lights, for air conditioning, and they use atriums as a natural energy conservation

feature. I'm not saying that those figures are right but I noticed the approach on those buildings is different from the one in the buildings we have seen and in general different from the architecture we have seen in Canada, where we have a severe climate. The buildings being designed are of an international type of architecture and the building could be in New York City, it could be in California and it could be in Calgary. There really isn't any difference and I find this quite interesting.

K. Jaeggins, Public Works Canada

I'm sure some of the award winners came from California. Their energy bylaws or energy codes and the restrictive nature of these codes, particularly on design, forced the architectural community there to do something about it. A good case in point is the Public Works Department in that state and the large scale of public buildings that have gone under construction since about 1978 using energy-conserving features of the type that Elliott mentioned and they are showing results. And you are getting consumption down into the range of 400 megajoules per square metre and I think we will find in Canada over the next five years more architects becoming aware of these issues and start to respond. But up to the present time they just have not had a chance or have not been interested.

R. Biggs, National Research Council

I lived in the San Francisco area for a couple of years and I know that 80°F was an exceptionally hot day in that city. It very rarely happened and hardly ever knows the winter so that is a somewhat easier climate to deal with.

S. Dubash, Public Works Canada

We will have to get the measurement of energy use back to some fair basis. We may say that a building uses 18 units of energy per square metre, per square foot or what have you, but when you are trying to equate two buildings, one may use 100 square feet per person and another may use 150. Now if you had the same area that was under-utilized, the utilization factor of that building is not taken into account. If both buildings are energy-efficient, then one is less or more because one was 18 and the other 16. One uses one and a half times as much per person as the other one, so that 18 units per square metre may turn out to be a more energy-efficient building than the one 16 units per square metre if you equate under the person basis. What are you using the building for anyway but to house people for an occupation or a task or just for living? It is this that really matters when you come right down to how efficiently you are using it. What is your energy coefficient per person occupying that space? You don't have to worry about the square footage, you don't have to worry about anything because it all equates back to that person. You use so much energy in the year for the person.

H. Elmahdy, National Research Council

That point was raised when Chrétien presented the building in Ste. Foy, Quebec and I think they used 30 square metres per person which, according to your comment, means that the space is under-utilized.

P. Gaudert, National Research Council

I think that an office building is not so much to house a person or employee, but has more of a functional nature. One can imagine in the year 2001 there may be one person on one floor, with computer terminals and automated equipment all around him. Instead, you have to take care that this person is comfortable enough to do his job.

S. Dubash, Public Works Canada

Still, you try to keep the person comfortable whether you use 10 square metres or 15 square metres of floor area. All these have to be taken into account. Then you have accountability in the final analysis when you come up with the figures based upon the person's use because that's the only fair way you can do it. If you have 300 people in the building you have to heat the building to keep those 300 people occupied at their jobs and during the period of time they are in, then you will see for yourself. At the present moment you find one person saying okay I'll have 150 square feet and another will be doing the same thing at 80 square feet, and others at 200 square feet. When you start looking at all these things it just doesn't equate.

D. Sander, National Research Council

What I had hoped to get out of this seminar was an answer to the question, "what is an energy-efficient office building". Frank Berry has suggested that maybe the examples we have seen are not quite his definition of an energy-efficient building. Also I had hoped to determine what are the characteristics of an energy-efficient office building and I guess what we all would like to get is a recipe on how to ensure that we get an energy-efficient building. The characteristics that you put on the board in your talk I don't think really represent distinctly an energy-efficient office building because they seem to be characteristics of almost any of our standard office buildings. Most of the things you described there seemed like pretty standard features. From my history of exposure to Frank's use of energy analysis and improved design procedures, I suppose what I was really looking for was some evidence that this extra sophistication that goes into design would appear as an input into an energy-efficient office building. Again I'm disappointed that I'm not sure I see any evidence of that and it seems to me that almost all of the buildings are the same and the ones that appear to have shown good performance probably, as someone indicated yesterday, happened to be constructed well and happened to be operated very well. So we are really looking at buildings that have not made any major errors as opposed to having some distinctly good characteristics.

H. Elmahdy, National Research Council

With regard to the features displayed on the screen, it was not meant to say these are the features of the energy-efficient office building. What I was trying to say is that all the buildings we studied here and the U.S. buildings that showed a lower energy consumption, employed almost the same features and if we and they use the same features and they come up with better numbers, either there is something wrong in the calculation or we are not taking full advantage of all these features. As for the other point you mentioned about the improved design, unfortunately you missed two of the

presentations this morning which outlined some ideas and the improved design of the HVAC system and I think I'll leave it up to Peter and Brian to comment on some of these features they presented.

B. Scally, Public Works Canada

I'm not currently active in energy studies directly but I have seen a lot of buildings over the years. We have done a lot of different types of work and I think almost starting with any building and in all the energy studies I have run into, the most important factor in making the building energy-efficient is the way it is operated. Generally speaking, when we have done an energy study we have found that the first thing you do is operate the building properly and you can save about 40 or 50% without spending five cents. It is just the way you operate and that's universal.

R. Biggs, National Research Council

How do you achieve that? How do you ensure that?

B. O'Donnell, Engineering Interface

Maybe I should introduce what Engineering Interface is doing now. The leading edge of our technology is to develop energy targets. We started out calling them energy budgets but when you say budget people think dollars. So we switched to targets. What we are saying is, "what should a building, any specific building, be using in energy?" That's dependent on a lot of things. First of all, we came up with the definition of a target and this is what we said: it's the lowest annual energy use needed for a building or a group of buildings to provide required environmental conditions and it must be obtainable through current investment criteria. Obviously it doesn't pay to make the insulation on a building so thick that you have no heating requirement. We saw the investment criteria as being important, whether the individual is erecting a new building or retrofitting an old one. If something that you are going to put into a building is going to pay off in two years, is that a good thing or a bad thing? Is five years a good thing or a bad thing? It varies from one person to another, from one group to another. The required environmental conditions are a constraint. In one building you may just have people. You may have computer equipment that has special considerations. What may be considered for energy efficiency added to a building in Toronto may not be applicable to Alberta because of the utility cost. Economic conditions reflect the rate of borrowing money. It all has an impact on your decision on what to go with, and the next one building of specific problems and opportunities. This is more to do with retrofit conditions where, for example, we would not normally recommend that someone upgrade wall or roof insulation because of the complexity of doing it. But suppose that a roof had to be replaced because it was leaking. Then it becomes worthy to consider adding more insulation to that roof. And in that building, use and occupancy have a lot to do with what sort of level is efficient because obviously a building that is occupied eight hours a day is going to use less energy than if it were occupied 24 hours a day and likewise if it had 300 occupants versus 1000 occupants. It's not a fixed thing. And so we are computerizing our target program to be a sister to our SUMAC program. We have loaded in all the characteristics of the building of one of our clients, then by changing one of those criteria we can then

recalculate an energy target or what sort of energy levels should apply to his building.

QUESTIONS AND ANSWERS ON INDIVIDUAL OFFICE BUILDINGS

THE MARSLAND CENTRE
Waterloo, Ont.

B. Jennings, Public Works Canada

There are serious implications in your delamping program, and so forth, that I would like to talk about. For example, the 100 foot-candles, is that a design figure?

B. Deuchars

That was the original design lined up.

B. Jennings

Let's assume that in this building the level would be 60% of 100, which would be 60 foot-candles or 600 LUX. You are using an air handling four-lamp troffer. The light output from a lamp depends on the temperature of the bulb wall temperature which is 77°F. What I am saying is that for a standard 40-watt lamp, manufacturers rate that either 3150 lumen or 3250 lumen based on a bulb wall temperature supposedly of 77°F. Now if you had taken a four-lamp troffer or luminaire and cut it in half you have done a number of things. First, you have reduced that one hundred or we said maintained a service level of 60-foot candles, you would reduce that considerably by almost half. You have further reduced it because of a lower or drop in temperature and probably the most important thing I noticed was that this building was constructed in 1971 which means that the ballasts in those luminaires usually have a life rating of 18 to 20 years. Now by removing the 40-watt lamp and substituting a 35-watt lamp (by the way, you're not getting 35, you're getting more like 38 watts) you now have the condition where the lamp and the ballast are not compatible. You are going to have premature failure of both the lamp and the ballast. Now this is the most serious implication in any delamping effort to conserve energy. We are very very concerned about the performance of equipment. We can look at savings in kilowatts, kilowatt-hours or what have you, but it is the performance of the equipment that is so important. So there are serious implications here concerning the performance of the lamp and of the ballast and the light output. That is what we are talking about or that is what the tenant is paying for, equipment life.

We have published a book on it, and we have had that kind of experience on some buildings.

But this is a very serious one because you simply cannot take a standard either two-lamp or four-lamp luminaire and put in 35-watt lamps without doing a cost-benefit analysis. And in a building as new as this -- it has been in operation only 12 years and the ballast life is probably 18 to 20 -- so if you were to do a cost-benefit analysis on that I would doubt very very much, well that 12 years might be marginal, but if it was, like the earlier speaker mentioned, for a building built in 1978 or 1979 there is no way that a cost-benefit analysis would prove or enable you to make that kind of a switch in ballast and lamp.

B. Deuchars

I think the owner had a hunch he was going on any recommendations at the time. It was the fashionable thing, I expect at the time, when he got on the bandwagon. He did with the full cooperation and appreciation of the tenants of the building with the exception of the City of Waterloo which occupied three or four floors to maintain the levels where they were. Everybody else seems happy with the life of the ballast.

B. Jennings

Lighting levels are not the thing we are interested in, really. It's the quality of lighting and the quantity of lighting. There is more to be gained by providing good quality of lighting than quantity.

Our concern about the performance of equipment, particularly lighting equipment, has caused us to be really concerned about the kind of data we are getting from manufacturers. We have serious doubts that a standard lamp supposedly rated 3250 lumen will actually give you 3250 lumen. You may get 3250 if you are lucky. You can have a ballast that will give you something different again and a luminaire. Those three things have to go together in order to give you good performance in a lighting system.

So far no one has mentioned lighting maintenance. Now in this paper or your work you have cut from 100 foot-candles you said was design, down to two-lamp luminaires which would be basically half. But that is initial and it is going to decrease so I think you are going for the tenant and the owner is going to end up with a problem. We had it, we still have it, where the lighting level is below recommended levels. For government buildings, normal offices, our standard calls for 550 LUX or 55 foot-candles. But that is based on a lighting maintenance or in-service illuminance. Preventive maintenance if you will. If you don't provide preventive maintenance then you go below the 550 LUX or 55 foot-candles and you will, I can assure you, seriously affect performance of the individuals.

B. O'Donnell, Engineering Interface

With respect to lighting, there are two points I would like to make. One is that since 1979 the lamp and ballast manufacturers did recognize that there was a problem with low-wattage tubes and they have changed the capacitance devices in the ballast now. So if you have a ballast in the building that is 1974 vintage or newer they should not have a problem there with switching to low-wattage tubes. Second, with respect to taking a four-lamp troffer and delamping to the lamps, that is certainly going to reduce the light output of the lamp. But one thing that does happen when you do that is that the coefficient of utilization of the fixture increases so you are not talking about 50% dropping by something less than 50%. You mentioned that they completely deactivated the preheat coils. Is there not a danger of freezing the cooling coil? I thought that the reheat was mainly a freeze protection feature.

B. Jennings, Public Works Canada

There is a point you raised there. The coefficient of utilization will change but it depends on which lamps you are talking about, whether they are

inboard, outboard lamps and so forth. I would like to mention that there was an excellent paper presented in Los Angeles three weeks ago by Lighting Science Incorporated which brought out all of these factors -- the photometry of luminaires, lamps, ballasts and so forth. Anyone interested in lighting design should read it.

B. Scally, Public Works Canada

Personally, I have never seen any building in Canada that benefits, in an energy point of view, from the installation of reflective glazing. Now I'm talking primarily computer energy studies, but we have had two cases this morning where people say it's positive. Can you really measure what you lose in the winter?

B. Deuchars

The manufacturer claims that the film increased the R value. But you will increase the heat gain through solar energy in summer and winter.

B. Scally, Public Works Canada

That was my point, and anything I have seen is that the change in the R value of the glass was very very tiny. Sure it is there, but it is almost immeasurable.

R. Biggs, National Research Council

The general conclusion though is dependent upon location in Canada and has to be dependent upon the ratio of glazing area to internal loads or something of that nature as well.

B. Scally, Public Works Canada

In general, for office buildings, which brings it down to some pretty stable conditions, usually there is a fair penalty for reflective glazing.

F. Vaculite, Public Works Canada

If you don't have clear glass, there is also solar energy captured by the body of the glass and you can develop a situation where the glass pane will warm up even in the wintertime and it will cause radiation which will affect thermal comfort. Now that's one problem. The other problem is when you have a great big pane of glass and it is partly shaded by the building across the street; you may have thermal stresses in winter. The third point is, who knows what's going to happen to the light on the other side of the glass? If the glass has certain colour changing in it, you may end up with a spectral light which may not be too healthy for your eyes. Some people observe that if they are behind certain types of glass, they start to feel irritation or other things.

S. Dupash, Public Works Canada

We did a study in which we did some delamping and whatnot within a building. The initial was 40-watt fluorescent lights. We introduced 35-watt fluorescent light lamps. We discovered in a building slated for

700 megajoules per square metre, the building itself being around 35 000 to 40 000 square metres, in Winnipeg, the total difference at the end of the runs on the ASE program was precisely 4 megajoules per square metre. Looking further, we then started doing the ERE runs reducing the electrical input from the lights on perimeter areas to see what would happen. What we discovered was quite clear, that the heat the lamps give out into the space -- not into the ceiling -- when it was cut down that heat is replaced by our perimeter heating unit. So when you make this statement, what precisely did you gain? What you were once initially feeding into the building as an input from the light as heat was now replaced by the input from your perimeter unit out on the side wall. That was item no. 1. Looking a little further, we started to see what we could do about various things, e.g., air flows through the lamps and so on. We went right down from approximately 2½ watts per square foot to about 1.5 watts per square foot for the electrical department because they wanted to see what would happen. Consistently what we discovered was that 70% of the heat, that is the heat that rises into the space troffers and not to the plenum, was made up by the perimeter units, and that there was no change whatsoever as long as the heating was required and that was put into account, and we did not gain anything by doing so. So insofar as the building energy is concerned, if you use your lights the light energy in the perimeter doesn't do anything for you.

REVENUE BUILDING
Ste. Foy, Quebec

B. Scally, Public Works Canada

I was not sure whether you were taking a credit or a debit for reflecting glass. Was that intended to show that it was a saving or an extra cost?

C. Roy

The net effect is saving - very marginal. Net effect is 1.6 kW-h/m^2/yr. Are these really net savings, because some of the lights of the building contribute to heating. And the heating season is obviously longer than the cooling season? Saving in light is to reduce electricity demand.

F. Berry

The direction I was hoping to go is as it is in Quebec; it is hydro-electric. We are not coming off on nonrenewable resources, and yet there doesn't seem to play in capital money cost, there is no consideration of that. I would have felt that the report would have been more useful to me if I could say, here is an area in Canada where we are using hydro-electric, where I am sure of the cost of electricity. What are they in Quebec, 3¢? Yet when I saw that complicated system there I got the running cost for energy efficiency, and I am saying, hey surely somebody would have projected that Hydro Quebec got a good deal from the Newfoundland government. I think here is where a total life cycle costing would have shown say, here is a case where maybe we shouldn't have such an energy-efficient building because we are going to be paying for it.

R. Biggs, National Research Council

What are the other operating costs of the building? It is certainly one of our concerns. Much that we are interested in conserving energy and so on, we recognize that energy costs are really a relatively small part of the total cost, whether they are 10%, or 20% of the owning and operating costs. When we consider the salaries of the employees working in those buildings they get even smaller. So we have a concern that one does not do cartwheels to save energy and jeopardize the productivity of the occupants of the building. That's why the question was associated with the lighting quality, and perhaps air quality. It is a side issue. I am not sure that's quite what you were getting at. I think you were getting at the capital cost but I wanted to bring that out as being one of the concerns we have and I know that people like Jim Davison have similar concerns.

H. Elmahdy, National Research Council

I noticed from the report on that particular building, that when the temperature outside is below -18°C, simply the exhaust air from the washrooms is introduced into the supply air. Is this a common practice and how does the building code in Quebec deal with this?

F. Barry, Public Works Canada

Well, looking at the drawing you are not actually doing that. You are putting it through a heat exchanger because it is illegal to put exhaust into it. It is against the National Building Code so surely the National Research Council should know that.

C. Roy

It is true that the exhaust air from washrooms is introduced into the supply air at that condition. This is how the building was designed.

R. Biggs, National Research Council

Since this is a provincial building, my understanding is that the provincial government, and the federal government for that matter, take the building codes under advisement. They are general guidelines and they are not necessarily in all cases obliged to follow them to the letter. Now I could be wrong, and the people from the National Capital Region may correct me, but my understanding was that the installation of carbon monoxide detectors in the garages at the National Arts Centre was against the building code, either of the city or province or whatever, at that time.

THE E.I. WOOD OFFICE BUILDING
Swift Current, Sask.

J. Davison, Public Works Canada

I was interested in the two values you have picked in the simulation on relative humidity. We have just been working with a building in Calgary where we have run into very low humidity. You use 15 and 25% relative humidities?

J. Osborne

Yes.

J. Davison, Public Works Canada

If my understanding is close on that, it is certain that 15% would be well outside the ASHRAE comfort zone. Is that typical across the Prairies?

J. Osborne

No, that is not typical. It was only included to demonstrate the effect of various levels of humidity ratios.

R. Monteyne, Vinto Engineering

15% relative humidity is not that untypical in the coldest winter temperatures. Generally we use a sliding scale of control and as the temperature drops you also cut back the relative humidity in the building. -35°F is not going to be around for too many days in a row, but sometimes you can get a very severe week and your humidity will be that low and you just can't afford to have it at 30% or 25% because double-glazed windows will have water running down inside them. So any leaks or infiltration points will have frost. That is fairly common practice.

J. Davison, Public Works Canada

We also notice that perceptions of humidity are quite different in the West because people are accustomed to much dryer houses in the winter. It wasn't perceived that this is a particularly significant problem relative to other problems in the building.

THE BELL CANADA ADMINISTRATIVE BUILDING
London, Ont.

C. Ray, CRS

I have a question regarding the heat pump system operation. Where does it draw its energy during the night? I understand that the building is in balance up to -10°C during the day but you have to heat it during the night.

P. Golem, C&B

The building operator tells us that the heat pump can satisfy all the heating needs of the building down to -10°C day or night. With most of the lights off. Remember that there is one area in the building that is occupied 24 hours a day and that's the telephone operator service. There is a substantial amount of electrical equipment in that area and of course there are a few people but the building operator tells us this and we have no reason to doubt his word. And I should also say that when I look at the reset schedule on the hot water supply and compare that to this -10°C figure, they are telling me where they have to switch over, that -10°C (outdoor) temperature is essentially at the point where the hot water reset schedule gets so hot that the bypass valve on the secondary bundle says "hey, I can't go through the secondary bundle, I'm going to blow the chiller apart". So it has to bypass. It almost seems that the switchover point is not controlled so much by heat losses on the perimeters but simply by protection of the chiller.

B. Scally, Public Works Canada

As I look at the breakout of the percentages there I would say the heat pump is running on the horsepower used to drive pumps all the time. With 14% pumps you add that 6% heating, you've got 20%. And basically with that high a pump circulating, all that energy ends up as heat and it would appear that that's what's happening. Instead of running ordinary heat you are just running its pumps and heating up the water.

G. MacIntosh, Public Works Canada

How do you think this building is sensitive to weather? I am curious to know how this building would perform in Calgary or Ottawa.

H. Elmahdy, National Research Council

The advantage of having low surface to volume ratio would contribute to that factor because the skin losses will be minimized. Also, since the interior zones require cooling almost year round, then you may not get substantial differences with the same building in Calgary, for example.

B. O'Donnell, Engineering Interface

I have something on Place Bell. We are presently working on a retrofit for that building. I'm not involved personally at the moment but if memory

serves me right, it is operating at somewhere between 40 and 50 kW-h per square foot per year. So it's not at top performance.

B. Scally, Public Works Canada

Was that corrected for an 8-hour day for this building? Did you sort out the 24-hour day ones and correct back with your computer that brought that figure or is that an actual figure?

P. Golem, C&B

That is essentially an actual figure. I have estimated it by estimating the various components of that figure but they correspond fairly well with the actual total consumptions.

B. Scally, Public Works Canada

So this allows for the fact that some of it is operated 24 hours a day. You didn't correct everything to what would be in the other part only run 8 hours a day, for instance?

K. Jaeggin, Public Works Canada

This building represents a sort of typical approach to energy conservation from an architectural point of view, with a low surface to volume ratio, large internal loading, with the exterior features in a minimum. What about the interior architecture? Are there any distinctive features about the building? I assume Bell Canada is very strict in the way they deploy their personnel in open office landscaping. They keep their screens to a certain size and they don't allow floor to ceiling walls to destroy the mechanical ventilation within the internal part of the building. So they are in pretty good control over other elements to balance the systems. Is there anything that you noticed? Anything unusual about the interior of this building?

P. Golem, C&B

Absolutely nothing. Roughly 40 000 square feet to a floor and you go down one end and you look down and see screens and filing cabinets and desks.

THE JOSEPH SHEPARD BUILDING
Toronto, Ont.

K. Jaeggin, Public Works Canada

One of the most obvious questions to ask is: were you able to, in your review of the information before going to the building, determine the proposed budget for energy consumption during the design phase and if in fact this building met the expectation of the designers in energy use?

A. Kobayashi

We did not, of course, design the building. It was originally designed by Engineering Interface. They have done studies to predict what the energy consumptions would be and we picked up the energy bills from about the previous two years, I believe 1980-1981 and 1981-1982, and the actual consumptions were reasonably close to the predictions. I think you would say that, yes the predictions were fairly accurate and it depends on the weather and how the building is operated. There have been numerous changes to the occupancies and some of the areas that were originally designated as store areas are now office areas for Air Canada and part of National Defence and so on. There is a recruiting centre, so there is air conditioning thrown in where it was not originally inspected. But generally, overall, we found that the predictions were fairly in line with the actual consumptions.

K. Jaeggin, Public Works Canada

The next question following on this is the premium paid for the energy conservation measures. Were you able to determine what in fact was a breakeven point in terms of years for this building and if these particular energy conservation measures were cost effective?

A. Kobayashi

In this particular study, we did not look at dollars. I did obtain the construction figures for the building but I don't have them with me and I cannot remember them. But the building was a little more costly than a typical office building; on the other hand the building construction was a little better than the development building.* So just going by memory I would have to say that the building was in line with the typical office building. I don't think there was a whole lot of premium paid for the energy conservation features. For things like lighting, for instance, there was a premium paid for putting the grid system in the slap, in terms of coordination, not necessary material, and there were savings because there were reductions in lighting fixtures so capital cost was not worth keeping within a reasonable percentage. The thing that might have cost a bit more was the perimeter radiation units because of the lower temperature and the radiation units had to be increased in size. But then you are saving on the heating bill, so based on that I would say that the building is a litlle more expensive than normal but not excessively.

*Estimated total cost of construction was $\$361/m^2$. (Source: Winning Low Energy Building Designs, Public Works Canada, 1980).

B. Scally, Public Works Canada

Do you have separate metering for the gas into the garage from the building? How were you able to separate that into actual bills and into actual costs?

A. Kobayashi

No, we don't have separate metering; the consumptions were separated strictly through pure simulation. The garages were taken off as separate zones, there are ventilation units serving the garages which require heating, as well as the thermal load and an estimate was made as to how long and how much these units operate. And taking that and putting it into a simulation you get numbers and subtract those from the total. That's how it was determined.

B. Jennings, Public Works Canada

Just two minor questions on item 1. You refer to an average illuminance of 807 LUX. Is that a field measurement? Is it a design measurement? Or what does it represent?

A. Kobayashi

It is a design measurement and that was based on studies that Public Works Canada had required during the original design phase and subsequent model offices. It was actually extracted from a paper that was written on this particular subject.

B. Jennings, Public Works Canada

It's a little higher than what you would expect, but I was just wondering what it was, what it did mean. On the other item, you mentioned an estimated yearly consumption for elevators of 18.6 $MJ/m^2 \cdot yr$. There are elevators and there are escalators in that building; was any attempt made to separate or to compare them?

A. Kobayashi

No, there were elevators. Escalators were contained in the miscellaneous and internal equipment. They were not singled out as a separate piece of equipment. So the elevators were strictly the 40 and 50 horsepower motors and I believe there is one extra freight elevator in the back of the building and for scheduling the elevators we contacted the elevator people and tried to get some indication on how much these things were used.

J. Davison, Public Works Canada

Did you make any attempts to determine either by measurement or simulation how much air leakage you were getting through the exterior building enclose?

A. Kobayashi

No. During the study I talked to Tom Tamblyn of Engineering Interface and Tom has done some work in this area. His findings were that the building was a little leakier than they had originally anticipated and he gave me some CFM figures that he semi-predicted -- it is a very hard thing to do -- and we used those figures with a daily schedule in the simulation. That's how we got a handle on what the infiltration might be. Otherwise it is a very difficult thing to put your finger on.

THE RED DEER PROVINCIAL BUILDING
Red Deer, Alta.

F. Berry, Public Works Canada

The thing that you have mentioned, that it is very difficult in Alberta to find a building that is below 1200 MJ/m^2·yr. I was shocked and I looked through my estimate of our inventory west of Edmonton of around 1500. An equivalent building I went to is 2200, that's for a standard government office building. What do you attribute that to? You have mentioned air leakage as one factor. But why is it so high? I was looking through the inventory here and we have buildings at 3500 and 3000 MJ/m^2·yr. Is it just lack of interest because maybe energy is so cheap out in Edmonton?

R. Monteyne, Vinto Engineering

In old buildings certainly. In the new buildings, we had such a construction boom that we got terrible contractors on some jobs. They didn't know what they were building so how could they make sure? They had no idea what an air seal was or what it was supposed to do. A lot of designers don't too. Our whole construction industry probably doubled in five years, so there are a lot of people who have no experience and surely and eventually learn that you have problems with freezing pipes, hidden behind the radiation cabinet. It is a mechanical problem, not enough heat in this room. I think it's probably that coupled with artificially low gas prices.

R. Biggs, National Research Council

Could I comment on one more factor which is not generally recognized as being particularly important in what we are talking about. Something called degree-days. We do have a few more of those than they do in the West. I was particularly noticing in Reg's chart that the proportion for heating in his building will be the largest of the seven we will see here today. The 60% is a fairly high number to expect for heating and that's the component that's attributable to that 5800 DDC. So I think there is a third factor in all fairness and perhaps we should have prorated our number.

C. Proctor, CMHC

The wind shear during a Chinook, anybody who has been there knows that's a big factor in heating, particularly for buildings up to about three stories and the geometry of that is pretty wild. The other problem that isn't recognized in Eastern Canada is that the West is very short on good engineers of any kind. I've worked in Western Canada for 15 years and the availability of good air conditioning people, ventilation and mechanical engineers of all kinds and yet B.C. and Alberta have a tremendous boom in 10 years. They have been putting up billions of dollars worth of buildings and it is not uncommon where major benchmark buildings were put up in the absence of the architects.

J. Davison, Public Works Canada

You have such a tight building which I think is definitely the way to go at the attention to the ceiling of the building but what kind of costs were you running on energy cost or dollar cost in terms of ventilation percentage? When you get your building enclosures so tight, then it becomes very critical that you in fact are delivering the ventilation air that you think you are when you are designing. A lot of buildings we have looked at from a performance perspective because the building is leaking. We are getting a natural ventilation which has saved the situation in many cases and when you are tightening the enclosure you are not getting any closer. When you're in Quebec it seems to me that your ventilating costs in that building or energy or dollar costs were very low.

R. Monteyne, Vinto Engineering

The fan power is very low. In that 63% for heating is where your ventilation is taking place really. We were surprised at the fan performance, particularly on the part load. Up to 75% of the volume down you have less than 75% of the input power and gets better all the way down. For VAV system, you never operate at full load. The air delivered into the building is something like 10 litres per second per person. Which is fairly generous and it is a free cooling system. In Alberta our weather is such that you are using free cooling of some form, some percentage.

R. Biggs, National Research Council

I observed with the VAV system that you went down to 25% low as a minimum but the building is relatively tight and you have in fact quite low lighting power levels and I was wondering with a low lighting power level that implies that the VAV boxes at 100% won't be too big. What does 25% look like, and do you have any air quality problems?

R. Montyne, Vinto Engineering

There have been no demonstrated or reported air quality problems. That is a problem that we are all facing as designers -- what you do with variable volume when you get down in an interior space of a building you get two watts per square foot of lighting and few people. There seems to be a tendency toward lower density in office buildings so you have 300 square feet per person. You have fewer people but you have almost no load interior zones so you could be easily supplying 0.4 cfm per square foot or something like that at peak. One of the things that we are thinking of doing is not increasing the outside air but increasing the circulating rate by 0.2 so you can artificially create four or six air changes per hour circulation in a room but really that's a little 1/30 of horsepower fan.

THE PUBLIC WORKS CANADA BUILDING
London, Ont.

J. Davidson, Public Works Canada

That was an excellent presentation Brian. We broke out the system part, the envelope part and the architectural part and the operations. And we are finding this same kind of results in buildings we are looking at. I have a couple of specific comments and questions. In the envelope area, the glazing wall ratio, I understand there is a real tradeoff in terms of the rent you get for space if the glazing ratio is 50% or more.

I know this building from a different perspective. It's a Public Works Canada Building and I ran into it because it had a very significant dissatisfied client, the employees of the building. I had represented Treasury Board in terms of some of the discussions that went on from a labour management perspective on this building, and it was perceived I think, as in the situation in most buildings, as an "air quality" problem. I know there were a couple of different studies done, one by Health and Welfare and one by an independent group, and as far as I know there hasn't been anything turned up specifically on the air quality side.

B. O'Donnell, Engineering Interface

I have not seen those studies and I don't know about the results of the work. The pressure system of the building right now is delivering approximately 30 cfm per person, higher then the ASHRAE recommendation. We used to talk about 10 cfm per person. A paper that ASHRAE recently published said that it's now recommended at 5 cfm for non-smoking areas, 20 cfm for smoking areas. I don't know what it is when you have an in-between situation. Certainly the building is over-ventilated. My understanding of what happened there is that in 1979 several motors in the building were downsized. For example, the fan on the fresh air was changed from a 25-horsepower motor to a 5-horsepower motor. I'm not quite sure how the employees coped with the changes or whether they really did start feeling stuffy or whether someone in the building started banging their drums saying, hey look how well we are downsizing the fans -- we got away with it. But from what I understand there was an uproar from the occupants based more on a newspaper article, and consequently the studies were done. The results of the studies I don't think had an awful lot to do with the band being related at its original size but they went down. I think there is a lesson to be learned there. Lots of buildings are over-ventilated and the lesson is, okay let's take it down but let's do it either gradually or conservatively. Let's not go for the big savings, such as going down to 5 cfm per person.

J. Davison, Public Works Canada

There are a lot of interesting questions in that whole area. I would just like to make one point. With all the presentations today, it would have been nice to be able to correlate some of the energy-efficient buildings to performance in the sense of different aspects of the interior environment, not only what's being actually delivered in the building. I know that's something we are working on and it's still quite a ways down the

road in terms of being able to do it efficiently. Just playing with your numbers, if you looked operationally at the building, if my quick calculations are right, for about 20 thousand square metres in that building and you are talking roughly these operational savings therefore in the order of something like $70,000 a year and maybe another $40,000 a year. How many employees are in that building? Around 1000. If you take some of kind of an average payroll cost and throw in some overhead costs, I think very conservatively you are looking at a $50 million dollar payroll in that building on an average basis and 1% of that is $500,000, so a fifth of a percent is in the order of $100,000. The point I'm trying to leave with the group in a sense here is that this is a good performing building, certainly from an energy point of view. It appears, as you were saying, to be delivering 30 cfm per person, quite a substantial ventilation rate, and yet we had a very significant loss of productivity because people were basically very upset with the indoor environment in that building. If you look in terms of a 1% change in productivity, you are looking at $500,000 a year.

B. O'Donnell, Engineering Interface

This is something I think we all have to learn. We are promoting energy conservation, energy management, but we have to look at the whole picture. One of the rules of thumb Mr. Tamblyn has right now is that the cost (you include salary in the building, capital and everything else) is about $100 per square foot per year. Now out of that $100, one is energy cost. So let's be careful about that one because it causes a ripple through the whole thing and you might end up having a lower energy bill but overall you are not ahead.

H. Elmahdy, National Research Council

The complaints about the stuffiness and deteriorating air quality may be due to something else besides the low rate of ventilation which is not the case if you are looking at 30 cfm/person. So it could be because of some other reason. Contaminants could be producing odours in the building. Do you know of any source of unusual conditions in the building?

B. O'Donnell, Engineering Interface

I am not aware of any source of contamination in the building.

G. MacIntosh, Public Works Canada

I have a comment and a question. We recently completed a study of a fairly tight building in terms of the enclosure and we did a tracer gas ventilation test with the fan off. We found that the leakage through the mechanical system passed the dampers was 10 times the amount of air leakage through the enclosure. We wanted to make sure that when we are looking at air leakage in a building you would include the equivalent leakage area passed through dampers. And along that line I have a question. I'm interested in the fact that they dump all the return air into the garage, is that correct, except for washer exhaust? Do they turn the washer exhaust off at night? So they are probably smaller units on their own time clock.

B. O'Donnell, Enginering Interface

Yes to the two questions.

G. MacIntosh, Public Works Canada

When all their fans are turned off and the building is essentially under stack effect in the winter time, how do they prevent aspiration through the garage doors up that return air shaft into the building and then out to the fresh air?

B. O'Donnell, Engineering Interface

Well, the garage ventilation system is carbon monoxide controlled, so it should be. On Monday morning I would think that the garage would be pretty clean. There is a possibility of contaminants going up that way. I have to confess I didn't really look into that closely.

G. MacIntosh, Public Works Canada

Although I'm not too sure if it is a bad idea, I was wondering if they have any backlogged dampers or anything like that to prevent that situation. Or to ensure that there is no migration of air up into the building.

K. Jaeggin, Public Works Canada

I wish to continue on with what Jim Davison referred to about the total cost in a building over its life cycle. I first came across a formula that was presented to a joint ASTM Committee Seminar in Philadelphia, in about 1971. It attempted to indicate that if you consider a total life of a building, assuming about 40 years, and the total cash flow through that building includes the cost of the production of what goes on in that building and if it is an office building, basically salaries, capital cost and operation have 92% of the total dollars that have been flowing through this building, 6% is operating costs and 2% is capital cost. And from all of the examples we have seen to date, out of that 2% of capital costs there really has not been much headway made in looking at the architectural features of energy conservation other than reducing the glazing approximately 10%, as you said in this example, from the norm, which had a great impact on the operation, i.e., the energy conservation. So certainly we are looking at a picture from a wider scope. You can see the real values of where we are spending our time in trying to save money and worker dissatisfaction obviously represents a big area that requires greater study in building environments.

B. O'Donnell, Engineering Interface

I don't know if the change from 25 to 35% glazing is a big thing to the workers. It may be more that their windows don't open and they think that the air isn't fresh enough.

R. Monteyne, Vinto Engineering

The thing we have to remember is that initially when energy conservation became popular it wasn't seen as a cost reduction measure, it

was seen as a necessity. And I think that the focus has changed. We started to realize that perhaps we are not running out of oil and everything else as quickly as originally predicted partly because of conservation. So now we have to wave the whole energy in terms of all these other factors. Before we did not have a choice.

B. O'Donnell, Engineering Interface (Comments on SUMAC Program)

Everybody is on the same level, the engineer, the operators, and we talked about what we saw in the building and then talked about what can be done to improve the building. And the results are fantastic because in the process the operator learns a lot about energy management, about the operation of his building systems and he also gains a new pride in operating his building. Then we go on and we monitor his building on a month-by-month basis. We compare his energy use for this particular month against that month in a reference year, or that month for a target year and he can see how much he is saving on a month-by-month basis or he can see if he is slipping or whatever. It's proven to be very effective. Take the school board in Toronto as an example. We had a group of 26 schools and 12 of them went on the workshop program for one year and the other 12 were to go on the next year. In the 12 that went on the program, the operators went back and did things to their buildings, didn't get anything, anymore capital budget than the other 12, but they saved $400,000 more. Just because the operators were in tune with what was going on.

F. Vaculik, Public Works Canada

I appreciate what you say, but I still would like to challenge you that this is not an ultimate solution. There is much more you can do for the operator. The problem with this approach, in spite of all the positive signs, is that if there is a personal problem between the operator and the building manager, you antagonize one or the other because they don't know what is happening in between and they will be scared. If you give him an indicator that he could follow from hour to hour or from day to day himself without asking anybody from outside, then he would be confident that he is doing a good job. That kind of information we ought to give and is something we are working hard at. What I'm trying to say is that there is a need for a type of engineering which is now common in other types of industry. We look at our building operation, a type of industry which produces an environment at certain quality levels and uses energy for it. We have to have indicators which will control the quality and which will control the performance of that production. And we are not near to that. So there is this kind of need for this type of engineer. Basically, the designers have all the knowledge except that they have to be able to require a challenge in this type of area and this way we would really improve the energy performance in buildings.

R. Monteyne, Vinto Engineering

For at least ten years we have also offered to our clients on every building, maintenance manuals which we have the contract to provide to a very rigid specification, but we also provide what we call a turnover seminar where we sit around the table with the building operators. However, those are not very effective because it is still all theoretical. The building is not working or it is working but no one knows how it will work

through a whole year of different weather. The other problem is that in 99 of 100 buildings, the building is not complete and things are hooked up wrong, things are controlling opposite to the way they are supposed to and these things may not get found out for 10 to 15 years. You go back into a building and see they have added coils because they could never get the temperature up when all they really had to do was change the reversing thermostat. And no one even discovered these things. That kind of commissioning is really needed and we are selling it, but no one wants to buy it.

D. Sander, National Research Council

The characteristic that seems to me to be common among the case studies we heard here is that even though some of them are relatively recent buildings, they all seem to really be describing a retrofit approach. Is it necessary to build and then retrofit or can you shortcircuit this process in some way?

P. Golem, C&B

My building really did not qualify because I needed two full years of operation. I didn't have it but I wrote this fantastic proposal that said how wonderful the building was and we should do it, so it was accepted. It was at the time that I did the study. I only had about 1½ years of data so it is really probably the younger buildings. And in fact, that building was, I've got to give the designers credit. They established an energy budget for the building, worked it out with Bell Canada. I really don't know where the incentive for that came from, but they established an energy budget for the various systems and for the total building and they designed their building to achieve that, and in fact it did achieve that and they also prepared some fairly extensive manuals for the operators. So I think that building may be somewhat unique in the group but I think it does show that it can happen. It is starting to happen.